CHEMICALS DIVISION OF THE WAR INDUSTRIES BOARD

Front row, left to right: J. R. Townsend, Dr. A. G. Rosengarten, Dr. E. R. Weidlein, R. M. Torrence, Charles Catlett, H. W. Sanford, Bernard M. Baruch, C. H. MacDowell, Ira C. Darling, F. A. Prosser. *Second row:* H. G. Carrell, W. A. Bush, J. A. Becker, W. G. Woolfolk, C. K. Leith, F. R. Atwood, A. R. Brunker, Dr. V. L. King, M. F. Chase, Maj. W. H. Geishenen, C. D. Tripp, Dr. T. P. McCutcheon. *Third row:* Maj. C. F. Sholes, Capt. H. C. DuBois, Lieut. F. A. Williams, Prof. H. E. Staley, E. J. Haley, Col. M. T. Bogert, J. M. Morehead, Prof. H. R. Moody.

AMERICAN CHEMICAL INDUSTRY

THE WORLD WAR I PERIOD: 1912-1922

By

WILLIAMS HAYNES

Volume II

New York
D. VAN NOSTRAND COMPANY, Inc.
250 Fourth Avenue
1945

PRINTED IN THE UNITED STATES OF AMERICA

CONTENTS

PART ONE: SETTING OF WORLD WAR I PERIOD

PART TWO: CRITICAL RAW MATERIALS

Chapter *Page*

15. THE POTASH DEBACLE 169

ON ANTICIPATED POTASH IMPORTS, PRICE FALLS BELOW COST—POTASH EMBARGO LIFTED, BUT CONTINUED SHORTAGES HEARTEN AMERICAN PRODUCERS—THEY BAND UNSUCCESSFULLY FOR PROTECTIVE TARIFF—KALI SYNDIKAT MAKES DEAL WITH AMERICAN FERTILIZER COMPANIES—AMERICAN TRONA POINTS WAY TO POTASH INDEPENDENCE.

16. PHOSPHATE ROCK AND ELEMENTAL PHOSPHORUS . 182

WAR COST U. S. LEADING POSITION AS WORLD SUPPLIER OF PHOSPHATE ROCK—WESTERN DEPOSITS RISE AND FALL—WAR DEMANDS FOR ELEMENTAL PHOSPHORUS MET BY OLDBURY—SWANN DEVELOPS ELECTRIC-FURNACE PROCESS—TARIFF OF 1922 PROTECTS NEW PHOSPHORUS CHEMICAL MAKERS.

17. PYRITES TO BRIMSTONE 195

UNION SULPHUR COMPANY POISED TO CAPTURE WORLD MARKET—CURTAILED PYRITES SHIPMENTS FROM SPAIN AND DISAPPOINTING OUTPUT FROM U. S. MINES FORCE ACID MAKERS TO ADOPT SULFUR—CRITICAL SHORTAGES NECESSITATE RIGID CONTROL OF ALL SULFUR MATERIALS.

18. GULF COAST SULFUR 206

GULF COAST DOMES EXPLORED FOR OIL; SULFUR FOUND—FREEPORT SULPHUR BRINGS FIRST TEXAS DOME (BRYANMOUND) INTO PRODUCTION—GOVERNMENT PUSHES DEVELOPMENT OF BIG HILL BY TEXAS GULF SULPHUR—SULPHUR EXPORT ASSOCIATION FORMED—ACID MAKERS' CONVERSION TO SULFUR COMPLETE.

19. CRITICAL METALS 219

ELECTRIC FURNACE PLUS CHEMICAL CONTROL HASTEN DEVELOPMENT OF FERROALLOYS: TITANIUM, TUNGSTEN, MANGANESE, VANADIUM, ZIRCONIUM, CHROME—PIONEER WORK OF F. M. BECKET—WAR INDUSTRIES BOARD COMMANDEERS PLATINUM—AMERICAN MAGNESIUM RETAINS TWO SUPPORTERS POSTWAR.

20. MISCELLANEOUS MINERALS 239

MERRIMAC MAKES DEAL WITH ALUMINUM COMPANY ON SOUTH AMERICAN BAUXITE—DOMESTIC BORAX IN BRITISH CONTROL FULFILLS WAR NEEDS—U. S. ACHIEVES INDEPENDENCE IN BARYTES—TALC AND SOAPSTONE PRODUCERS PROMOTE WAR-WON MARKETS—OIL REFINING EXPANDS DOMESTIC FULLER'S EARTH INDUSTRY.

21. CHEMISTRY TOUCHES NAVAL STORES 254

SHERMAN ANTI-TRUST LAW HINDERS REORGANIZED NAVAL STORES INDUSTRY—YARYAN INTRODUCES STEAM-SOLVENT RECOVERY PROCESS—NEWPORT DEVELOPS WOOD-ROSIN EXTRACTION—INDUSTRY STABILIZED BY FEW, LARGE PRODUCERS AND CHEMICAL TECHNOLOGY.

22. CRUDE DRUGS 266

AGRICULTURE EXPERIMENT STATIONS AND COLLEGES OF PHARMACY PROMOTE DRUG-FARMING—GROWING OF LICORICE, BELLADONNA, DIGITALIS, ETC., FLOURISHES—CELLULOID AND DU PONT FAIL TO ESTABLISH CAMPHOR IN FLORIDA—CRUDE DRUG MARKET HIGHLY UNORGANIZED AND SPECULATIVE—ONLY NATIVE DRUGS SURVIVE POSTWAR SLUMP.

Page

APPENDIX

ILLUSTRATIONS

INTRODUCTION

A GREAT MANY AMERICANS think that we kidnaped our chemical industry from the Germans under the protecting guns of the British Grand Fleet during the First World War. That is a completely erroneous belief. And yet the great growth of that period so overshadows all the childhood ills and lusty youthful development which preceded it, that even some chemical people—who should know better—will forgetfully date the birthday of the American chemical industry somewhere between 1914 and 1918. Rather, these were the four years of college when this vigorous young industry burned midnight oil mastering stiff courses in technology and economics; during which it grew up, found itself, realizing for the first time the man's part it would be called upon to play in our modern world.

The impressionable, formative years of an industry, as of an individual, are important and very interesting. They cannot be ignored. In the case of an industry they explain a great deal about its organization, its keenest rivalries and strongest alliances, its trade customs, its relations with customers, and its habit of thought as revealed in its policies.

Therefore, since I have deliberately elected to publish first the second and third volumes of this history of the chemical industry in the United States, covering the years 1912 to 1922, I must at the outset make two points clear.

First, the origins of this industry did not spring from the First World War.

Second, the publication of these two volumes out of their natural chronological order was prompted by reasons that seem to me logical and valid.

In the autumn of 1608, that redoubtable braggadocio, Captain John Smith, shipped from Jamestown in Virginia the first cargo of American manufactured wares. It was consigned to the London Company, financial backers of that ill-fated colony, and its manifest included "tryals of pitch, tar, glass, frankincense, and soap-ashes." Thenceforward naval stores and pot-ashes were important items in colonial commerce. To them must be added sassafrass for the purveyors of blood tonics; oak and hemlock barks for the tanners; and later indigo for the dyers.

In 1636 at Boston, John Winthrop, Jr., son of the Massachusetts governor, set up a chemical laboratory. Fifteen years later he promoted the first American chemical stock company to produce saltpeter.

The American chemical industry is thus rooted firmly in the earliest commercial enterprises of our colonial days. Ever since that time the manufacture of chemicals in the United States has grown steadily and quite consistently. By 1914, when the First World War broke out, we were producing nearly as much sulfuric acid as Germany and Great Britain combined. Measured by this favorite yardstick of chemical activity, we had certainly laid down a solid foundation in the production of those basic inorganic chemicals essential to all chemical processing.

Ten years later we were producing more than twice as much sulfuric acid as were Germany and Great Britain, as much sulfuric acid as these two plus France, Belgium, and Japan. The American chemical industry had grown to be incomparably the largest in output, but at the same time it had widely diversified its products. During this period, changes in the economics of the industry were as great and lasting as its technological advances, so that the years 1912-22 covered by these two volumes, witnessed the advent of an entirely new epoch.

We enormously widened our chemical operations, not only by rounding out our production of inorganic materials and by excursions into the field of organic chemicals, but also by greater, and sometimes quite new applications of processes involving the high-pressure synthesis of gases, fermentation, electrolysis, and the use of high temperatures, notably in the electric furnace. These expansions and diversifications introduced an entirely new era in American industrial chemistry, an era characterized by the development of the synthetic plastics and resins, the exploration of natural gas and petroleum as chemical raw materials, and the employment of electrical energy as a chemical tool. In these broad areas of chemical activity American chemists and chemical engineers, American apparatus makers and chemical manufacturers have established impressive leadership.

In addition to this technological progress, the period of the First World War initiated radical changes in the outlook and organization of the American chemical industry. The imperative need for chemicals made clear for the first time the key position these tools of modern industry had come to occupy. The close cooperation required of chemical producers in the war effort gave them a new sense of national importance and responsibility. Chemical manufacturers became industry-conscious just when the American people became suddenly aware that chemicals are important to national prosperity and vital to national defense. The individual owner-manager had all but vanished and the family-owned chemical companies were fast becoming corporations whose shares were widely owned and publicly traded in. The war publicized the industry, and by creating a market for chemical securities, hastened these changes and paved the way for the consolidations of the booming twenties.

While the organization of the industry was in these ways revised to conform to the usual American pattern, a revolution took place in chemical sales methods and policies. The old sales agents were replaced by the company's own salesmen, and though the manufacturers thus took distribution into their own hands, they gave up a measure of their control over chemical prices by fundamental changes in the terms of their sales contract. What previous to the war had been a mutually firm commitment—the seller to supply and the buyer to take a specified quantity of a given chemical at an agreed price—became little more than a buyer's option to take a quantity loosely defined as "buyer's requirements" at a price that was protected against decline. These changes in the strictly business aspects of chemical manufacturing were quite comparable in their effects to the impacts of the new products and modern techniques upon the industry.

So revolutionary were the results of these technical and economic changes wrought by the war, that the entire character of the industry underwent complete metamorphosis. The transformation was as distinct and startling as the butterfly that emerges from the cocoon which encased the caterpillar. It is therefore quite logical to start the history of the modern chemical industry in this country at the time when this distinctly new phase began, that is, during the period of the First World War.

From the chemical point of view this embraces more than the actual war years. It starts properly with the election of Woodrow Wilson who initiated a program of legislation, including the Clayton and Federal Reserve Acts, a strengthened Pure Food and Drug Law, and a tariff for revenue only, all of which affected the chemical industry significantly. At the other end, the mop-up of surplus war chemicals and the violent readjustment of prices in the short, sharp depression of 1920, also belong to the war story. The period was definitely closed by the passage of another and quite different tariff, the Fordney-McCumber Law of 1922, whose much criticized, highly protective rates undoubtedly saved the lives of our war-born chemical industries in immunizing them from deadly, ruthless German competition.

Two other very practical considerations have prompted me to publish Volumes II and III first. I was certain that the following pages would be more valuable and much more interesting because of the first-hand information—facts, figures, and illuminating incidents—from men who played active roles in the chemical drama of the First World War.

So important is this personal, off-the-record material that I hastened to submit the first rough draft of each chapter to men familiar with the particular events that it records. The footnotes and references testify how much these volumes owe to their generous, friendly assistance. At the end of this volume I have made more complete, adequate acknowledgment of such help.

Each year new vacancies thin the ranks of the veterans. Already Herty, Poucher, and Garvan—the famous Three Musketeers of the dye tariff fight—are gone. The rich stores of information held in the memories of William H. Nichols, John Queeny, and H. H. Dow are locked forever. Three great trail-blazers, Washburn in air nitrogen, Becket in metallurgy, and Baekeland in plastics, would have been priceless collaborators. I have been keen to gather and preserve as much original testimony from such leaders as possible. It is invaluable and irreplaceable. These compelling considerations urged me to start work on the First World War period as quickly as possible.

Exactly opposite reasons make it expedient to devote as much time as possible to the collection of material for the first volume. The facts and figures of our early chemical history are widely scattered. The first technical journals, *The Boston Journal of Chemistry* and *The Journal of Applied Chemistry*, were both started in 1866, and our oldest trade paper, *The Oil, Paint & Drug Reporter*, has been published continuously since 1871. Before that, save for some excellent but sporadic reports of the Census Bureau and occasional surveys fathered by various learned societies and sundry commercial associations, the information is unorganized. C. A. Browne, the late Edgar Fahs Smith, and a few other historically minded chemists have unearthed much of the early history of American chemistry, but they have been chiefly interested in science and technology, and except for isolated dates of the founding of certain companies, the field of chemical business is almost virgin territory. Certainly very little has been done to correlate the development of chemical manufacturing and merchandising with the economic development of the United States, or to set the American chemical industry against its contemporary political and social background. I have particularly wanted to paint this broader picture accurately. The more time taken in collecting the facts, verifying them and studying their meaning, the more nearly can this goal be approached.

From this comprehensive point of view these two volumes are significant chiefly because they chronicle the beginnings of the Chemical Revolution. By this I mean a fundamental change in the economic system of production: the replacement in industrial processes of natural raw materials by synthetic materials. This change is as important as the Industrial Revolution. It is as apt to revolutionize our industries, our laws, and our mode of living. None of us can as yet even guess all that man-made raw materials will mean to the human race.

Medicines, fertilizers and insecticides, fibers, plastics and elastomers, gums, waxes, resins, and glues, perfumes and flavors, even alloys which are synthetic metals, all of them are man-made to exacting specifications for our use of their physical characteristics and chemical properties. Any one of them may be produced in any country regardless of climate or the accident of natural resources. They are unlimited in supply, yet controllable as to output. They are free from the vagaries of weather, insect attack, the ravages of plant and animal diseases. A new kind of product, they defy the old law of supply and demand, since the greater the demand, the larger the production; the bigger the production, the lower the price. In bold opposition to the chancy crops and harvests, the failing forests, the depleted oil wells and mines of the old economy of scarcity, they are plainly the materials of an economy of abundance. With their allies, the chemical processes which create sunlight and control temperature and humidity, they are powerful weapons in man's age-old fight against a niggardly and dangerous environment.

In the long run, this Chemical Revolution through which we are living will prove the most important event of these eventful years. The Napoleonic Wars absorbed the thoughts and energies of Europe at the very time when a few crude, leaky steam engines were first being put to work pumping water, turning wheels, weaving textiles. Napoleon redrew the map of Europe. But those spluttering engines have built our cities, rewritten our laws, revolutionized our lives. Again the very base of our entire economic system may be overturned, this time by synthetic materials. They are certain to force us to revise entirely our conceptions of world resources and world trade. They give a completely new meaning to "have not" nations and furnish new objectives for international diplomacy. In industry increased use of chemical materials and chemical methods will revolutionize mass-production processes. Many prices will be based upon chemical, not physical values. Established rates of depreciation and obsolescence will no longer hold good, and many manufacturers will have to get some brand-new ideas about costs and profits.

Already these radical changes are upon us. They imply new economic and political problems to be solved, social readjustments that must be made. It is my hope that as a footnote to the history of our times my attempt to explain the origins of the Chemical Revolution will help to a clearer understanding of these unavoidable implications.

The methods and aims of this Revolution will be the central theme of the two volumes to follow.

The history of the American chemical industry during the eventful decade 1912 to 1922 might very easily be buried beneath a mass of facts; the forest lost in the trees. Between 1917 and 1922, for example, 393 distinct companies made coal-tar chemicals in this country. By 1923 a majority of these had disappeared. Most of the others lost their identity in mergers. Only a few have persisted to influence this branch of chemical manufacturing. For the sake of the record, the names of all 393 are listed in the Appendix of Volume III, but I have made no effort to write the full story of all these enterprises.

A definitive history of chemical manufacturing in the United States in all of its ramifications, a complete chronicle of all companies and men, of every process and plant, would not only put unconscionable burdens upon the author and his readers, but it would defeat its own purpose. In such an encyclopedic work, the main line of our chemical development would be obscured by details. Selection is essential to clarity. But, because selection inevitably focuses upon the companies that prosper, the methods that work well, the products that win markets, the men who wield influence, it concentrates upon the larger and more successful undertakings. Any research worker quickly learns that the careful record of a failure may contain exceedingly useful information. Negative data have positive values, and I have sometimes recorded somewhat in detail undertakings that did not succeed, not by way of invidious comparison, but to preserve a proper sense of balance. Year after year the facts and figures of this complex, highly interrelated industry accumulate like piles of jackstraws. To compose this jumbled mass of data into a definite comprehensible pattern is, so I take it, the first duty of any economic historian.

WILLIAMS HAYNES

Stonecrop Farm
Stonington, Connecticut
March thirtieth, 1944

CHEMICAL CHRONOLOGY, 1912-22

In an industry whose activities are so far-flung and complex, often so intimately interrelated, yet sometimes so independent that they appear to operate in a vacuum, it is exceedingly difficult to synchronize and correlate the events into a comprehensive pattern. This Chronology has been designed to help the reader connect the developments in the different branches of the American chemical industry during the years 1912-22—of necessity disjointed in their presentation in the following pages—so as to form a clearer, more connected picture of the chemical activities of the First World War period. It is frankly selective and within a given year the time-sequence of events has not been strictly followed, the first object being to group the facts so as to achieve clarity and emphasis. While based upon the events as recorded in these two volumes, I have drawn freely upon the Chemical Chronology that Dr. Lawrence W. Bass and I compiled at the time of the Chemical Industries Tercentenary in 1935, the annual chronology of *Chemical Industries*, and the yearly reviews published by that journal, by the *Oil, Paint & Drug Reporter*, and *Chemical & Metallurgical Engineering*. (W. H.)

1912

GENERAL

Chemical business good except sulfuric acid, due to poor fertilizer season and competition of by-product acid from new smelter recovery; by-product ovens supplied a third of U. S. coke.

National Association of Manufacturers of Medicinal Products organized.

Remsen Board barred saccharin in foods (Mar. 11).

Government sued Sugar Trust.

Food & Drugs Act amended (Sherley) to control misbranding.

Potash beds in West Texas discovered, J. A. Udden.

Legislative agitation for U. S. patent law reform.

Second International Opium Conference at The Hague (Aug.).

Eighth International Congress of Applied Chemistry, Washington and New York (Sept.).

Journal of the American Pharmaceutical Association published.

Carnegie Corporation of New York founded.

INDUSTRIAL-COMMERCIAL

First flaked caustic soda on market, Niagara Alkali Co.

Standard Alcohol Co. alcohol-from-sawdust plant, Georgetown, S. C., sold to du Pont.

Solvay Process Co. purchased Kansas Chemical Manufacturing Co.

First Midwest lithopone plant, Beckton Chemical Co., Chicago.

Freeport Sulphur Co. mined sulfur in first Texas dome, Bryanmound (Nov. 12).

New companies and incorporations:
- Amalgamated Phosphate Co.
- American Trona Corp.
- W. Beckers Aniline & Chemical Works
- Chicago Copper & Chemical Co.
- Dermatological Research Laboratories
- Farmers' Fertilizer Co. of America
- Freeport Sulphur Co.
- International Smelting & Refining Co.
- New Jersey Testing Laboratories
- Newport Rosin & Turpentine Co.

1913

GENERAL

Another poor fertilizer season and 70 plants closed; U. S. became world's largest sulfuric acid producer and supplied 26 per cent of world's phosphate rock.

Hearings on chemical schedules of proposed tariff bill (Jan. 6).

Du Pont bought Chile nitrate mines; H. J. Baker & Bro. appointed American nitrate agents for Antony Gibbs & Co., London.

Mellon Institute of Industrial Research founded (Mar.).

INDUSTRIAL-COMMERCIAL

Du Pont Powder Co. dissolved by Federal Court order; Hercules and Atlas organized.

General Chemical Co. built Marcus Hook plant.

American Coal Products Co. dissolved under anti-trust laws.

St. Joseph Lead Co. merger with Doe Run Lead Co., largest U. S. lead producer.

Virginia-Carolina Chemical Co. began plant in Carteret, N. J.

1912

TECHNICAL-SCIENTIFIC

Thiogen and Hall processes for recovery of sulfur fumes.

Petroleum cracking, W. H. Burton.

Liquid chlorine in water sterilization, Electro Bleaching Gas Co.

Air-nitrogen by Pauling process, Southern Electrochemical Co., at Nitrolee, S. C.

Carbon black in rubber compounding.

Potash from cement, Cottrell electrolytic precipitation, Riverside Portland Cement Co., Calif.

Calcium phosphate, Newberry-Fishburne process.

Chlorine-detinning process, Goldschmidt Detinning Co.

Weizmann discovered bacteria for butyl alcohol fermentation (England).

Haber process (air-nitrogen) installed at Oppau, Germany.

Cresson medal, E. W. Morley, physical chemistry.

Gibbs medal, T. W. Richards, atomic weights.

Nichols medal, Charles James, organic chemistry.

Perkin medal, Herman Frasch, desulfurized petroleum and sulfur mining.

CONTEMPORARY EVENTS

New Mexico and Arizona admitted to the Union.

Sun Yat-sen: Chinese Republic.

Discovery of South Pole announced by Amundsen.

Titanic sunk.

Dutch planters and German manufacturers formed quinine syndicate.

Minimum wage law enacted in England.

Riker-Hegeman retail drug merger.

Coal and railway strikes (summer).

Italy-Turkey war ended.

Balkan War.

Woodrow Wilson elected president.

1913

TECHNICAL-SCIENTIFIC

Radium produced commercially, Standard Chemical Co.

Basic ductile tungsten patent granted to W. D. Coolidge.

Panchromatic plates and colored light filters, Eastman Kodak Co.

Arsenic fumes recovery plant, Anaconda Copper, Great Falls, Mont.

Saybolt oil absorption process for gasoline from natural gas, Hope Natural Gas Co.

CONTEMPORARY EVENTS

U. S. Parcel Post in operation.

Mexican Revolution.

Second Balkan War.

U. S. Personal Income Tax passed.

1913 (*Continued*)

GENERAL

"Sulphonal" trade-mark case, Farbenfabriken *vs.* Lehn & Fink, withdrawn without decision.

National Canners' Association set up Washington research laboratory.

American Naval Stores Co., sued in test Sherman Law case, went into bankruptcy.

Underwood Tariff Act signed (Oct.); followed by sharp business slump.

Federal Reserve Act passed (Dec.).

American Chemical Journal merged with *Journal of the American Chemical Society.*

Membership of American Chemical Society passed 6,000.

INDUSTRIAL-COMMERCIAL

Pacific Coast Borax Co. bought Smith interest in Death Valley deposits.

Concentrated Acetylene Co. reincorporated as Prest-O-Lite Co.

Godfrey L. Cabot purchased Penn Carbon and West Virginia Carbon Companies.

New companies and incorporations:
- American Agricultural Chemical Co. (merger)
- Atlas Powder Co.
- W. J. Bush Citrus Products Co.
- Globe Naval Stores Co.
- Hercules Powder Co.
- Prest-O-Lite Co.
- Rosin & Turpentine Export Co.

1914

GENERAL

Failing demand and falling prices checked abruptly by war in Europe; quick advance in prices, but exports disrupted and war boom developed slowly.

Textile Alliance incorporated (Feb.).

U. S. Department of Labor created.

Pittsburgh Experiment Station, Bureau of Mines, established.

Rockefeller Foundation founded.

Bureau of Chemistry set up rosin standards.

National Drug Trade Conference formed.

Weekly Drug Markets founded, D. O. Haynes (Aug.).

INDUSTRIAL-COMMERCIAL

Stauffer Chemical Co. bought Russell Borax Mining Co.

Columbian Carbon absorbed 5 companies—first big consolidation in carbon black field.

R. W. Greeff & Co. opened American branch.

Bacchus plant of Hercules Powder Co. built.

Increased commercial production of gasoline from natural gas.

American rights to Ekström process, alcohol from sulfite waste liquors, West Virginia Pulp & Paper Co.

War shortages of phenol, potash, cyanides, mercury, coal-tar dyes, medicinals.

First safety glass in U. S., Safetee Glass Co., Pittsburgh.

Merck & Co. entered manufacture of coal-tar medicinals.

1913 (*Continued*)

TECHNICAL-SCIENTIFIC

Mallinckrodt produced barium sulfate for X-ray diagnosis.

Pyrites cinder reworked for iron.

Victor Chemical Works replaced bone by rock in manufacture of baking powder phosphates.

American Trona Co. attempted exploitation of Searles Lake brines.

Gibbs medal, L. H. Baekeland, photography, electrochemistry, plastics.

Perkin medal, James Gayley, dry-air blast iron smelting.

CONTEMPORARY EVENTS

16th and 17th Amendments to U. S. Constitution passed.

General strike in Belgium and much labor trouble all over Europe.

Germany refused British proposal for "naval holiday."

1914

TECHNICAL-SCIENTIFIC

Sodium cyanide by Castner-Roessler process, Roessler & Hasslacher.

Lilly began manufacturing Lloyd's reagent and biological products.

Panchromatic motion-picture film, Eastman Kodak Co.

Pyrex glass, E. C. Sullivan, Corning Glass Works.

Townsend cell, later Hooker cell, improved (C. P. Townsend, Elmer Sperry, Leo Baekeland) and Hooker Electrochemical Co. plant enlarged.

Naval stores by steam-solvent process, H. T. Yaryan.

Flotation of lead ores (Federal Lead Co., H. A. Guess) generally adopted.

First chlorobenzene made in U. S., Niagara Alkali Co.

Synthetic black iron oxide by precipitation process, Binney & Smith.

Redmanol, phenolic plastic, L. V. Redman.

Thyroxin isolated, E. C. Kendall.

Calorization process, General Electric Co.

Dry chlorination recovery of sulfide ores, Northwestern Metals Co.

CONTEMPORARY EVENTS

Franz Ferdinand of Austria murdered (June 28).

U. S. Marines occupied Vera Cruz.

World War I began (Aug. 2).

First ship through Panama Canal.

New York Stock Exchange suspended four months.

Germany embargoed coal-tar dyes.

Battle of Mons.

Battle of Marne.

France embargoed glycerin.

1914 (*Continued*)

GENERAL

Turpentine Farmers' Association formed (Sept.).

Clayton Act signed (Oct.).

Insecticide Manufacturers' Association organized.

Federal Reserve System in effect; 12 regional banks.

Harrison Narcotic Law passed (Dec.).

War tax on perfumery and cosmetics.

INDUSTRIAL-COMMERCIAL

Potash Products Co. first potash plant at Jesse Lake, Nebr.

Goodyear Tire & Rubber Co. and U. S. Rubber (Naugatuck Chemical Co.) made aniline for self-consumption (Nov.).

New capital investment in chemical industries, $16,838,000.

New companies and incorporations:
- Abbott Laboratories (name changed)
- American Camphor Co.
- Aetna Explosives Co.
- S. B. Penick & Co.
- Takamine Laboratory
- Van Schaack Bros. Chemical Works

1915

GENERAL

Acute shortage of many drugs and chemicals, notably potash, nitrate, and coal-tar dyes and medicinals; U. S. coal-tar industry, 6 producers of crudes, 17 of intermediates, 12 of dyes; new capital investment in chemical industries, $65,565,000.

Month's record exports of sulfuric acid, 6,361,579 lb. (Feb.).

Mellon Institute dedicated.

Federal Trade Commission created.

Last regular shipment of dyes from Germany (Mar. 19).

Technical Section of the American Paper & Pulp Association organized.

Eastman Kodak ordered by Courts to dissolve monopoly.

Procter & Gamble *vs.* Berlin Mills set patent precedent that product cannot be described in terms of the process (Burchenal).

INDUSTRIAL-COMMERCIAL

Ammo-Phos Corp. bought Amalgamated Phosphate Co. property, Chicara, Fla.

Sulfur black made commercially, E. C. Klipstein & Sons.

California Fruit Growers' Exchange began manufacturing citric acid and essential oils from oranges and lemons.

Krebs Pigment & Chemical Co. mined barytes in Georgia.

Du Pont bought Arlington Co., manufacturers of Pyralin.

Fifteen new benzol-recovery plants installed.

Mergers:
- Eagle-Picher Lead Co.
- Electro Bleaching Gas Co. with Niagara Alkali Co.

New companies and incorporations:
- Air Reduction Co.
- American Aniline Products, Inc.
- American Barium Co.
- American Bromine Co.
- Avery Chemical Co.

1914 (*Continued*)

TECHNICAL-SCIENTIFIC

Seaman continuous wood-chemical retort patented.

Manufacture of reagent chemicals begun at Illinois University, C. G. Derick (Aug.).

Merck produced hydroquinone.

Chandler medal, L. H. Baekeland, "Some Aspects of Chemical Industry."

Cresson medal, E. F. Smith, electrochemistry.

Gibbs medal, Ira Remsen, organic chemistry.

Nichols medal, Moses Gomberg, free radicals.

Nobel prize, T. W. Richards, chemistry.

Perkin medal, J. W. Hyatt, plastics.

CONTEMPORARY EVENTS

Fall of Antwerp.

U. S. Marines landed in Haiti.

German naval victory off Coronel virtually stopped nitrate shipments.

Great Britain declared war on Turkey (Nov. 5).

Von Spee's fleet destroyed off Falklands.

1915

TECHNICAL-SCIENTIFIC

Carrel-Dakin solution and chloramine introduced as wound antiseptics.

High-chromium iron alloys (Stellite), E. Haynes.

Department of Agriculture approved *p*-dichlorobenzene as seed and grain fumigant.

Nelson chlorine cell patented.

Carus Chemical Co. made potassium permanganate.

Hydrogen-ion concentration studies, W. M. Clark.

Vitamin studies begun, Osborne, Mendel, McCollum.

Aluminum chloride refining of petroleum, A. M. McAfee.

Activated sludge sewage process applied.

Dry lime-sulfur insecticide developed.

Potash from alunite, Mineral Products Co., Marysvale, Utah.

First barium peroxide in U. S., Rollin Chemical Co.

CONTEMPORARY EVENTS

London Stock Exchange reopened after five months.

U. S. transcontinental telephone service.

Germany declared embargo on potash; began unrestricted submarine warfare (Feb. 18).

Panama-Pacific International Exposition.

First use of flame-throwers by Germans (Feb. 26).

British Orders in Council listed most chemicals as contraband.

British confiscated *Ogeechee's* chemical cargo.

First poison gas attack of war, Second Battle of Ypres (Apr.).

1915 (*Continued*)

General

First National Exposition of Chemical Industries, New York City (Sept.).

Naval Consulting Board formed.

Many bills for air-nitrogen program introduced in Congress—none passed.

Second Pan American Scientific Congress.

First meeting of Insecticide & Disinfectant Manufacturers' Association.

Department of Chemical Engineering founded at Columbia University, M. C. Whitaker.

Industrial-Commercial

C. F. Burgess Laboratories
Calco Chemical Co.
California Fruit Growers' Exchange
John Campbell & Co.
Casein Co. of America
Curtis Bay Chemical Co.
Dye Products & Chemical Co.
Federal Dyestuff & Chemical Co.
Imperial Color Works
E. C. Klipstein & Sons
Koppers Co.
Newport Chemical Works
Standard Aniline Products Corp.
Warner-Klipstein Chemical Co.

1916

General

Supply of chemicals began to meet war demands and many price declines; coal-tar crude output surpassed $30,000,000; chemical exports over $165,000,000; new capital investment in chemical industries, $99,244,000.

Liggett-United Drug chain formed by merger.

Record of all chemical price advances: acetphenetidine, 84¢ to $42.

50% increase in sulfuric acid production over 1915.

Technical Section reorganized as Technical Association of the American Pulp & Paper Industry (TAPPI).

National Committee of Physicians for Medical Preparedness formed.

Massachusetts Institute of Technology moved to Cambridge; offered first degree in chemical engineering.

National Defense Act signed (June).

American exports under licensing.

Chlorine shortage for poison gas; extensive application of liquid chlorine in industry.

National Research Council organized (July); Chemistry Division formed.

Industrial-Commercial

Muriate of potash (prewar, $39.07) sold for $475 (Jan.); commercial production of potash at Searles Lake, American Trona Corp.; Government experimental kelp-potash plant, Summerland, Calif., J. W. Turrentine.

First smelting of Bolivian tin in U. S., American Smelting & Refining Co.

Curtis Bay chemical plant built, U. S. Industrial Alcohol Co.; acetone made by vinegar process.

First electrolytic alkali plant west of Mississippi, Great Western Electro-Chemical Co., Pittsburg, Calif.

Warner-Klipstein built electrochemical plant at Charleston, W. Va.

Bothamley Chemical Co. absorbed Frank L. May Co., dyemakers.

Innis, Speiden & Co. organized manufacturing unit, Isco Chemical Co.

Calco Chemical absorbed Neidich Process Co.

Fairfield Rubber Co. (rubber-coated fabrics) bought by du Pont.

1915 (*Continued*)

TECHNICAL-SCIENTIFIC	CONTEMPORARY EVENTS
Sponge rubber from latex patented, P. Schidrowitz and H. A. Goldsbrough.	*Lusitania* torpedoed by German submarine.
Edible lactic acid, Avery Chemical Co.	Italy declared war on Austria (May 23).
Franklin medal, T. A. Edison, inventions.	
Gibbs medal, A. A. Noyes, analytical and physical chemistry.	Allied embargo on platinum exports; cotton declared contraband.
Nichols medal, Irving Langmuir, physical chemistry.	Henry Ford peace ship to Europe.
Perkin medal, Edward Weston, electrochemistry.	U. S. protectorate over Haiti.

1916

TECHNICAL-SCIENTIFIC	CONTEMPORARY EVENTS
Titanium dioxide as pigment patented (Barton), Titanium Alloy Manufacturing Co.	First Battle of Verdun.
First production of chrome black, Semet-Solvay Co.	Rebellion in Ireland.
Successful adaptation of formate process, Victor Chemical Works.	Compulsory military service in England.
Benzene recovered from carbureted water gas, Koppers Co.	
Washington magnesite used in refractories.	German I. G. organized (May).
First American commercial oxidation of ammonia, Ammo-Phos Corp., W. S. Landis.	Battle of Jutland.
Arsenic recovered from cadmium, R. H. Stevens process.	France and England lifted embargoes on glycerin.
Production of magnesium from chloride by electrolysis, Dow Chemical Co.	
University of Illinois opened laboratories for summer production of organic reagents.	Yellow Fever Commission, under Rockefeller Foundation, left for South America
X-ray methods in industrial problems, General Electric Co.	Battles of the Somme.

1916 (*Continued*)

GENERAL

German submarine, *Deutschland*, docked at Baltimore with cargo of dyes and medicinals (July 9).

Federal Trade Commission found trade abuses but no monopoly in fertilizer industry investigation.

Artificial leather commercially important.

Chinese tungsten mines discovered.

National Defense Council and Advisory Commission created (Aug.).

Shortage of coal-tar dyes created abnormal consumption of natural dyes.

Emergency Dye Tariff passed (Sept. 8).

Naval Consulting Board completed survey of industries.

First official specifications for tank-cars for gas shipments.

Deutschland at New London, Conn., with second chemical cargo (Nov. 1).

Chemical Engineering Catalog founded.

INDUSTRIAL-COMMERCIAL

Semet-Solvay Co. contracted to build Government ammonia-oxidation plant.

Durex Chemical Corp. (Toch Bros.) bought barytes property in Tennessee.

Second Newport naval stores plant built at Pensacola, Fla.

Sodium permanganate made by Kalbfleisch Corp.

New companies and incorporations:
- Century Colors Corp.
- Columbia Naval Stores Co.
- Commonwealth Chemical Corp.
- Florasynth Laboratories
- Grace Nitrate Co.
- Great Western Electro-Chemical Co.
- Isco Chemical Co.
- Michigan Electrochemical Co.
- New York Color & Chemical Co.
- Salt Lake Chemical Co.
- Utah Chemical Co.

1917

GENERAL

U. S. entry into war created new demands for chemicals and resulted in many controls, chiefly under War Industries Board; new capital investment in chemical industries, $146,160,000.

Inter-Department Board studied Government air-nitrogen sites.

Blight destroyed American chestnut as source of tanning extract.

Turpentine & Rosin Producers' Association formed.

First large shipment of chemicals to U. S. from Japan (potassium chlorate).

Munitions Standards Board, later General Munitions Board, created.

McGraw-Hill Publishing Co. formed by merger.

INDUSTRIAL-COMMERCIAL

First U. S. imports of British Guiana bauxite, Merrimac Chemical Co.

Du Pont bought Harrison Bros., first chemical expansion by purchase.

Du Pont entered coal-tar dye business.

Many efforts to supply soda ash from natural carbonate in Western brines.

Russian Government shipped 4,000 tons potassium carbonate made from sunflowers.

Synthetic indigo produced commercially, Dow Chemical Co.

Brenton mine (Virginia) operated by Chipman Chemical Engineering Co. for arsenic trioxide.

Critical shortage of sulfur-bearing materials: Union Sulphur Co. agreed to "fair price" of $22 a ton for brimstone at mine.

1916 (*Continued*)

Technical-Scientific

Atropine extracted from Jimson weed by Eli Lilly & Co.

Bureau of Chemistry conducted education campaign in naval stores industry.

Basic chromium sulfate for one-bath tanning, Mutual Chemical Co.

First U. S. production of cyanamide, American Cyanamid Co.

Chandler medal, W. F. Hillebrand, "Our Analytical Chemistry."

Franklin medal, T. W. Richards, atomic weights.

Gibbs medal, W. R. Whitney, industrial chemistry.

Nichols medal, C. S. Hudson, sugars.

Perkin medal, L. H. Baekeland, photography, electrochemistry, plastics.

Contemporary Events

Italy declared war on Germany (Aug. 27).

Chloropicrin used as war gas by Russians (Aug.).

Jones Act for Philippine self-government.

Tanks first used by British (Sept. 15).

Woodrow Wilson reelected president.

Lloyd George coalition Prime Minister.

1917

Technical-Scientific

First tungstate toners in U. S., Kuttroff, Pickhardt & Co.

Citric acid by fermentation (Currie), Chas. Pfizer & Co.

Arc-nitrogen process in operation at La Grande, Ore., American Nitrogen Products Co.

Chloropicrin introduced as grain fumigant (W. Moore).

Organic mineral-flotation agents developed.

Calcium arsenate first used against boll weevil, U. S. Agriculture Experiment Station, Tallulah, La.

Gibbs-Conover phthalic anhydride process by direct oxidation of naphthalene (June).

Contemporary Events

Germany resumed unrestricted submarine warfare (Feb. 1); U. S. broke off diplomatic relations (Feb. 3) and armed merchant ships.

Russian Revolution (Mar. 12).

British Government took control of food, mines, wages, prices, censorship.

U. S. purchased Virgin Islands from Denmark.

1917 (*Continued*)

GENERAL

Nitrogen fixation abroad studied by Ordnance Department.

Bayer entered trade-mark "Aspirin" suit against United Drug Co.

War Industries Board created (July 28); first price fixing on copper (Sept.).

Sulfuric acid makers organized to meet acid shortage.

Alien Property Custodian created.

Food & Fuel Control Act passed.

Alien Property Custodian seized German chemical patents (Aug.), which were licensed by Federal Trade Commission.

Government commandeered chlorine, caustic, platinum, wood chemicals, etc.

War Trade Board created.

Potash Leasing Law passed.

Emergency War Revenue Bill law (Oct.).

Trading-with-the-Enemy Act signed (Oct. 12).

Chemicals Division of War Industries Board organized (Nov.).

Arsenic industry under Food Administration control.

National Tanning Extract Manufacturers' Association organized.

War Service Committees met in Washington.

Nitrate Executive, Allied buying pool, set up in London (Dec.).

Chemical, Color & Oil Daily (later *Chemical Age*) founded by Batters and Tufts.

American Chemical Society initiated press service.

INDUSTRIAL-COMMERCIAL

Government contract for modified Haber plant at Muscle Shoals with General Chemical Co. (Sept. 20).

Titanium from Florida beach sands, Buckman & Pritchard.

Stauffer Chemical Co. built Vernon, Calif., plant; later moved East.

Federal Dyestuff & Chemical Co. in receivership.

Mutual Chemical Co. bought chrome mine in Quebec.

Du Pont bought Marokene Co. (pyroxylin-coated fabrics).

Government contract for cyanamide plant at Muscle Shoals with American Cyanamid Co.

War Industries Board bought 235,000 tons German-owned nitrate from Chilean Government; du Pont acquired two new nitrate fields in Chile.

Calco produced cinchophen.

Mergers:
- Atlas Powder—Celluloid Zapon
- Kalbfleisch Corp.
- National Aniline & Chemical Co.
- Union Carbide & Carbon Corp.

New companies and incorporations:
- American Magnesium Corp.
- American Nitrogen Products Co.
- California Alkali Co.
- Chemical Production Co.
- Consolidated Chemical Co.
- Fields Point Manufacturing Co.
- Grasselli Powder Co.
- Rohm & Haas Co.
- Swann Corp.
- U. S. Industrial Chemical Co.
- Western Alkali Refining Co.

1917 (*Continued*)

TECHNICAL-SCIENTIFIC

Pyrethrum extract in kerosene spray insecticides.

Gas masks first manufactured in U. S.

Salvarsan made in U. S. by H. A. Metz Laboratories.

Isopropyl alcohol from petroleum hydrocarbons, Melco Chemical Co.

University of Oklahoma established industrial research fellowships in oil and gas.

Gates Chemical Laboratory built at California Institute of Technology; new chemical laboratory at University of Cincinnati.

Optical glass manufacture expanded: Bausch & Lomb, Pittsburgh Plate Glass Co., and Spencer Lens Co.

Eastman Kodak began manufacture of rare reagent chemicals.

Sheet window-glass machine introduced.

Liquid hydrocyanic acid gas commercially available.

General conversion of sulfuric acid manufacture from pyrites to sulfur.

Crude anthracene produced first time in U. S.; three manufacturers.

First sodium hydrosulfite made in U. S., Rohm & Haas Co.

Rubber companies established 30 industrial scholarships at University of Akron.

Gibbs medal, E. W. Morley, atomic weights.

Perkin medal, Ernst Twitchell, saponification of fats.

CONTEMPORARY EVENTS

U. S. declared war on Germany (Apr. 6).

Overman Act, giving Pres. Wilson war powers, passed.

Battle of Flanders.

First U. S. troops in France (June 26).

Strikes at Chilean ports held up nitrate shipments (summer).

Bolshevist Revolution (Nov. 7).

Supreme War Council in London.

Revolution in Portugal.

U. S. declared war on Austria (Dec. 7).

Russo-German Armistice.

1918

GENERAL

Chemical prices passed war peak, began definite decline; 128 producers of 177 coal-tar intermediates; over 58,000,000 lb. of some 300 different dyes made; production of ethyl alcohol passed 50 million gal.; new capital investment in chemical industries, $73,403,000.

Fuel shortage closed all plants for 2 weeks (Jan.).

Ammonia industry under Food Administration control.

U. S. Government Explosives Plants Department formed under Jackling.

Special Committee on Acids appointed by Chemical Alliance (Feb. 6).

Fertilizer manufacture under Agriculture Department licensing.

New War Industries Board created under Baruch (Mar. 4); commandeered, allocated, and fixed prices of toluene, platinum, mercury, acids, sulfur, pyrites, etc.

Dyestuff Manufacturers' Association of America, later American Dyes Institute, organized.

Webb-Pomerene Act signed (Apr.).

War Trade Board cut pyrites imports from Spain to conserve shipping.

Infringement of Frasch patents by Freeport Sulphur Co. sustained.

Chemical Warfare Service organized under Maj.-Gen. Sibert.

U. S. Dyestuff & Chemical Importers' Association organized.

Perryville ammonium nitrate plant (Navy-Atlas Powder) by Brunner-Mond process, in operation (July 8).

American Zinc Institute formed.

INDUSTRIAL-COMMERCIAL

Du Pont completed Deepwater dye plant.

Monsanto Chemical Works bought Commercial Acid Co.

War Dept. contracted for 1,000,000 lb. sodium bromide from Dow Chemical Co.

Government began building 8 wood-chemical plants; other Government plants in production: Old Hickory, Nitro, Sheffield, and Perryville in July; Muscle Shoals in Nov.; Saltville in Dec.

Metal & Thermit Corp. succeeded Goldschmidt Thermit Co.

First American production of alizarin, National Aniline & Chemical Co.

Scarlet, crimson, tartrazine, and methylene blue marketed by Calco Chemical Co.

Du Pont bought dye department of United Piece Dye Works.

International Nickel opened Port Colborne, Ontario, refinery (July 1).

Alcohol-gasoline (10-90) blend offered by U. S. Industrial Alcohol.

Federal Dyestuff reorganized as Union Dye & Chemical Corp.

Glycerin price fixed at 60¢, Aug.-Sept.; 58¢, Oct.-Nov.; 20¢, Dec.

Cyclone shut down Union Sulfur Mine (Aug. 6); in full production two months later.

Babbitt's lye business bought by Mendelson Corp.

Trinitroaniline produced by Calco (Sept.)

Spanish-American Iron Co. (Bethlehem Steel subsidiary) bought chrome mine in Cuba.

Aniline Dyes & Chemicals, Inc. (A. F. Lichtenstein) took over Geisenheimer & Co.

W. F. Sykes & Co. acquired American dye rights of St. Denis (France).

Trinitroxylene produced by du Pont, Chas. L. Reese (Oct.).

1918

TECHNICAL-SCIENTIFIC	CONTEMPORARY EVENTS
Parke, Davis & Co. introduced Type I antipneumococcus serum.	Wilson made "fourteen point" speech.
Duplitized X-ray film produced by Eastman Kodak Co.	Food strike in Germany.
Carbazole made in U. S.	Food rationing in England.
H. J. M. Creighton effected electroreduction of mannose to mannitol.	Treaty of Brest-Litovsk.
Hall process for toluene tried at Standard Oil plant, Bayonne, N. J.	International Tin Executive set up.
Diaspore in refractories technology, W. S. Cox.	German peace with Roumania and Russia.
Ethyl butyrate and propionate produced, Hercules Powder Co.	Last air raid on London (May 19).
De Jahn air-nitrogen process patented (General Chemical Co.).	First German retreat on Western Front (May 26).
Silica gel in refrigeration and absorption investigated.	Association of Quinine Manufacturers in Allied Countries formed.
Commercial production of phthalic anhydride, Gibbs-Conover process.	Inter-Allied Quinine Committee negotiated contract with Dutch syndicate.
Helium extraction begun in U. S.	Hindenburg Line broken (Sept. 27).
Acetone production by fermentation process at Terre Haute, for British.	Third German peace note to Wilson (Oct. 4).
Vulcanization of rubber by selenium, Chas. R. Boggs.	Widespread influenza epidemic.
Synthetic acetic acid from acetylene at Keokuk Dam by Canadian Electro Products Co.	

1918 (*Continued*)

GENERAL

Sulfur under control of Chemical Alliance Committee (Aug. 1); sulfuric acid prices fixed at $18 a ton for 60°; $30, 66° (to June), later (Sept.) at $16 and $25, respectively.

First *Census of Dyes* (1917), published by Tariff Commission.

First synthetic ammonia produced at Muscle Shoals (Sept. 16).

Dye Section of the American Chemical Society organized.

Largest electro-alkali plant (Nelson cells), Chemical Warfare Service, Edgewood Arsenal.

War Minerals Bill enacted (Oct. 5).

Federal Trade Commission organized Export Trade Division.

Journal of the American Ceramic Society founded.

INDUSTRIAL-COMMERCIAL

Bayer Co. sold to Sterling Products which resold coal-tar dyes to Grasselli (Dec.).

Pennsylvania Salt bought Michigan Electrochemical plant at Menominee.

Maywood Chemical Works (Dr. Ludwig Schaefer), consolidation of Thorium Chemical, Standard Essence, and Schaefer Alkaloid.

Dow and American Magnesium only postwar producers of magnesium.

New companies and incorporations:
- Alphano Humus Co.
- American Cellulose & Chemical Manufacturing Co.
- Federal Phosphorus Co.
- Heyden Chemical Co. of America.

1919

GENERAL

War controls over chemicals abandoned promptly and Government canceled contracts; lawsuits; dumping of surplus; sharp drop in chemical prices; 116 producers of 216 coal-tar intermediates, 76 new; new capital investment in chemical industries, $112,173,000.

War Industries Board dissolved (Jan. 1).

Chemical Foundation incorporated, Garvan president, to administer seized enemy-owned patents.

U. S. Fixed Nitrogen Administration formed to dispose of Government nitrate plants; sent Commission abroad to study nitrogen-fixation plants.

Francis P. Garvan named Alien Property Custodian.

U. S. Potash Producers' Association formed.

U. S. Alkali Export Association organized.

INDUSTRIAL-COMMERCIAL

U. S. surplus phenol to Monsanto for sale at 8¢ lb.

Tennessee Copper organized Southern Agricultural Chemical Corp. and bought phosphate mine at Bartow, Fla.

First vat dyes made in U. S. by du Pont, followed by Newport.

Tennessee Products Corp. took over Government Bon Air wood-chemical plant at Lyle, Tenn.

Texas Gulf Sulphur first production, Big Hill (Mar. 19).

American Aniline Products bought Stanley Aniline Chemical Works, Lock Haven, Pa.

Merck & Co. stock sold by Alien Property Custodian.

Germans offered $20,000,000 in dyes, per month, in reparation payments (May 1).

C. H. Herty sent abroad to negotiate for vat dyes (Sept.).

1918 (*Continued*)

TECHNICAL-SCIENTIFIC

Bucher cyanide process in production at Saltville, Va.

Du Pont established 18 fellowships and 33 scholarships at 17 colleges and universities.

Gibbs medal, W. M. Burton, petroleum chemistry.

Nichols medal, T. B. Johnson, pyrimidines.

Perkin medal, A. J. Rossi, ferrotitanium.

CONTEMPORARY EVENTS

Collapse of Turkish Army (Oct. 30).

Austria accepted Armistice (Nov. 3).

Republicans won heavily in U. S. Congressional and State elections.

Rioting in Berlin; Kaiser fled to Holland (Nov. 10).

Armistice signed (Nov. 11).

1919

TECHNICAL-SCIENTIFIC

Maleic acid synthesis by oxidation of benzene, Weiss and Downs.

Mercurial antiseptics introduced, Hynson, Westcott & Dunning.

High-frequency induction furnace, E. F. Northrup.

First American casein plastics, Aladdinite Co.

Liquid chlorine applied in paper industry, Electro Bleaching Gas Co.

Electrolytic white lead patented, E. A. Sperry.

p-Dichlorobenzene used against peach borer (E. B. Blakeslee).

CONTEMPORARY EVENTS

Theodore Roosevelt died (Jan. 6).

Sankey Committee Report on coal industry (England).

18th Amendment to Constitution (Prohibition) adopted.

New nitrate cartel formed in Chile.

Trade between U. S. and Germany-Austria resumed.

Goodyear Tire & Rubber Co. started rubber plantation, Sumatra.

Railroad strike in England; general strike in Barcelona, Spain; cotton strike in Bombay, India.

1919 (*Continued*)

GENERAL

Chemical Foundation injunction against Anglo-French Drug Co. for importing arsphenamine.

American Society of Biological Chemists organized.

Steel and soft coal strikes.

Graham House Committee investigation of war expenditures in Ordnance Dept. (July to Feb. 1921).

Textile Alliance handled reparation dyes for War Trade Board.

Volstead Act passed (Oct. 28).

Government sued Monsanto on test case to prove saccharin harmful to health (case withdrawn 1925).

Wyoming carbon black-gas conservation law; upheld by Supreme Court.

INDUSTRIAL-COMMERCIAL

Commercial Solvents Corp. bought Government butyl alcohol plants at Terre Haute.

First postwar shipment of German dyes, 165 barrels, arrived in New York (Nov. 5).

Charleston Industrial Corp. bought Nitro smokeless powder plant.

New companies and incorporations:
- Atmospheric Nitrogen Corp.
- Commercial Solvents Corp.
- Diamond Alkali Export Co.
- Fries & Fries
- Fritsche Bros.
- Huntington Chemical Co.
- Mackie Pine Products Co.
- Rhodia Chemical Co.
- Southern Agricultural Corp.
- Vanadium Corp. of America

1920

GENERAL

Prices sharply deflated, many war chemical dealers failed, general business depression; anti-freeze use of alcohol became important; 119 producers of 236 coal-tar intermediates, 70 new; anthraquinone output from phthalic over 500,000 lb.; more than 360 coal-tar dyes made; large expansion in syntans.

During fiscal year, War Trade Board licensed dye imports totaling 9,388,296 lb.

Prohibition and Volstead Acts went into effect (Jan.).

Industrial Alcohol Administration created under James M. Doran.

INDUSTRIAL-COMMERCIAL

General Chemical Co. first plant in Rocky Mountains area, with purchase of Western Chemical Manufacturing Co., Denver.

Allied Chemical & Dye Corp. formed by merger.

Pittsburgh Plate Glass Co. absorbed Columbia Chemical Co.

Guggenheims invested in Bolivian tin industry.

Union Dye & Chemical Corp. failed.

Monsanto Chemical Works bought half interest in R. Graesser, Ltd. (England).

Eastman Kodak Co. bought Kingsport methanol plant.

Standard Oil Co. (N. J.) acquired Ellis process for commercial production of isopropyl alcohol from petroleum.

Sherwin-Williams bought Frank Hemingway, Inc. (insecticides).

Ault & Wiborg Co. sold coal-tar colors business to Cincinnati Chemical Co., Swiss syndicate.

1919 (*Continued*)

TECHNICAL-SCIENTIFIC	CONTEMPORARY EVENTS
Cooperative chemical research by Tanners' Council, at University of Cincinnati.	Italian Government controlled export of lime citrate.
Research fellowships established by Rockefeller Foundation in National Research Council.	Peace Conference in Paris; Treaty of Versailles (June 28).
Pittsburgh Experiment Station, Bureau of Mines, opened.	International Trade Conference, Atlantic City, N. J.
Gibbs medal, W. A. Noyes, physical chemistry.	President Wilson paralyzed.
Perkin medal, F. G. Cottrell, electrical precipitation.	U. S. Senate refused to ratify Versailles Treaty and League of Nations Covenant.

1920

TECHNICAL-SCIENTIFIC	CONTEMPORARY EVENTS
Pyroelectric production of phosphoric acid, Federal Phosphorus Co.	U. S. railroads returned to private owners.
"Light resistant" lithopone introduced by New Jersey Zinc Co.	
First U. S. production of methyl chloride for refrigeration, Roessler & Hasslacher Chemical Co.	Columbian Carbon and General Electric of Great Britain formed United Lamp Black Works (England).
Sperry electrolytic process for basic lead carbonate, International Lead Co.	
Plant Protection Institute organized by National Research Council.	English Unemployment Insurance Act passed.
Monel metal applied in industry.	
Triphenyl and tricresyl phosphates introduced as plasticizers.	
Standard Oil (N. J.) produced isopropyl alcohol commercially—first chemical from petroleum.	Counterrevolution in Berlin ended by general socialist strike.

1920 (*Continued*)

GENERAL

Largest vanadium mine (Primos Chemical Co.) bought by Vanadium Corp.

Southern Dyestuffs, Nitro Products, Seydel, Rubber Service Laboratories, Federal Chemical, American Viscose bought Government war plants at Nitro, W. Va.; du Pont bought part of Old Hickory powder plant for rayon subsidiary.

New societies: American Oil Chemists' Society; American Society for Steel Treating; American Institute of Fertilizer Chemistry.

INDUSTRIAL-COMMERCIAL

Hercules Powder bought Yaryan Naval Stores Co.

Atlantic Dyestuff Co. (sulfur colors) moved to larger plant, Portsmouth, N. H.

National Lead, Eagle-Picher, Sherwin-Williams, and du Pont produced over 90% total U. S. white lead.

New companies and incorporations:
- Carbide & Carbon Chemicals Corp.
- Cincinnati Chemical Works.
- Du Pont Fibersilk Co.
- Hirsch Laboratories.
- Southern Dyestuffs Co.
- Tennessee Eastman Corp.
- Tubize Artificial Silk Co. of America
- Wishnick-Tumpeer, Inc.

1921

GENERAL

Gradual recovery of general business stopped decline of chemical prices; consumption of many chemicals approached wartime volume; 107 producers of 232 coal-tar intermediates, 49 new; nitrocellulose lacquers output increased threefold in two years to 1,409,280 gal.

Licensing of fertilizer industry ended by repeal of Food & Fuel Control (Lever) Act (Mar.).

Phosphate Export Association formed.

Emergency Tariff Act, with dye-licensing provision, passed (May); embargoed oxalic and formic acids, amyl and butyl alcohols, butyl acetate, fusel oil.

First state purchase of insecticide for at-cost distribution; Georgia, $100,000 for calcium arsenate.

INDUSTRIAL-COMMERCIAL

Atmospheric Nitrogen Corp. synthetic-ammonia plant at Syracuse in operation.

Anhydrous alcohol produced, U. S. Industrial Alcohol Co.; also 30 new esters, isopropyl alcohol, diethylcarbinol.

Hurricane wrecked Freeport and Texas Gulf sulfur operations (June 21).

Du Pont began manufacturing rayon.

Henry Ford first bidder ($5,000,000) for Muscle Shoals nitrate plants (July).

Great Western Electro-Chemical Co. made zinc chloride and hydrochloric acid by original processes.

Triacetin (glyceryltriacetate) offered as camphor substitute, Kessler Chemical Co.

Powers - Weightman - Rosengarten started manufacturing analytical reagents.

1920 (*Continued*)

TECHNICAL-SCIENTIFIC

Thyroxin marketed, E. R. Squibb & Sons.

Electrolytic sodium made in Downs cell.

Chandler medal, W. R. Whitney, "The Littlest Things in Chemistry."

Gibbs medal, F. G. Cottrell, electrical precipitation.

Grasselli medal, Allen Rogers, "Industrial Uses for the Shark and Porpoise."

Nichols medal, G. N. Lewis, physical chemistry.

Perkin medal, C. F. Chandler, chemical achievements.

CONTEMPORARY EVENTS

19th Amendment to U. S. Constitution passed.

Attempt to establish communism in Italy failed: Fascist party gained.

Harding elected President by large majority; Republicans in control of Senate and House.

1921

TECHNICAL-SCIENTIFIC

Oil emulsion dormant spray introduced by A. J. Ackerman against San José scale on apples.

Rubber latex directly utilized.

Hard rubber coating on metals, H. L. Fisher, Goodrich Co.

Liquid purification process for gases developed, Koppers Co.

Stanford Food Research Institute endowed by Carnegie Corp.

Mulford (F. M. Huntoon) introduced improved antipneumococcus extract.

American Institute of Textile Chemists & Colorists formed.

Science Service incorporated; began publishing *Science News-Letter.*

Organic Syntheses established.

CONTEMPORARY EVENTS

Insulin isolated by F. A. Banting, C. H. Best, and J. B. Collip (Canada).

Anatoxins discovered by Georges Ramon (France).

Anglo-Russian trade agreement.

Wood-Forbes report against Philippine independence.

Explosion of new gas plant, Oppau, Germany.

1921 (*Continued*)

GENERAL

"Aspirin" declared popular generic name by Courts.

American Dyes Institute replaced by Synthetic Organic Chemicals Manufacturers' Association.

American Institute Textile Chemists & Colorists founded.

Salesmen's Association of the American Chemical Industry organized.

INDUSTRIAL-COMMERCIAL

West End Chemical Co. organized.

34 American fertilizer companies contracted with German Kali Syndicat for 1922 potash requirements (Sept. 28).

American Phosphorus Co. closed down by foreign competition (Nov.).

Thatcher Process Co. formed to manufacture anthraquinone.

1922

GENERAL

Demoralized markets and inflated European currencies spurred demands for higher tariff rates on chemicals; chemical business continued recovery; 106 producers of 280 coal-tar intermediates; over 200% increase in production of vat and alizarin dyes; tar output greatest on record.

First U. S. imports of bauxite from Surinam, Dutch Guiana.

Textile Alliance gave up control of reparation dyes (Jan.).

Shortridge Senate Committee investigated alleged monopoly in dye industry (Feb.-May).

Chemical Division, Bureau of Foreign & Domestic Commerce, created.

Uniform chemical sales contract drafted.

Sulphur Export Corp. formed.

Government canceled options-to-buy contracts on Muscle Shoals with Alabama Power Co. and American Cyanamid Co.

Second investigation of fertilizer industry by Federal Trade Commission again found no monopoly.

Fordney - McCumber Tariff Act signed (Sept. 21).

Government unsuccessfully sued Chemical Foundation for return of patents and property assigned it (Sept.).

INDUSTRIAL-COMMERCIAL

Only three of 128 wartime potash plants in production.

Ethylene glycol manufactured commercially, Carbide & Carbon Chemicals Corp.

Bakelite Corp. formed by merger.

Control of Heyden Chemical Co. bought by B. R. Armour.

Aetna Explosives Co. liquidated.

Freeport Sulphur Co. leased Hoskins Mound from Texas Co.

Mathieson Alkali Works shipped liquid chlorine in multiple-unit tankcars; bought Commonwealth Chemical Corp.

War surplus chloroform condemned for deterioration and interstate shipments barred.

Powers - Weightman - Rosengarten added line of arsenicals.

Insulating board made, Celotex Co.

Dovan Chemical Corp. offered diphenylguanadine as rubber accelerator.

International Nickel refinery and rolling mill built, Huntington, W. Va.

Du Pont reopened synthetic camphor plant at Deepwater Point, N. J.

Dermatological Research Laboratories sold patents and plant to Abbott Laboratories.

1921 (*Continued*)

TECHNICAL-SCIENTIFIC

American Chemical Society Monograph Series, 1st volume, appeared.

Chandler medal, F. G. Hopkins, "Newer Aspects of the Nutrition Problem."

Gibbs medal, M. S. Curie, radium.

Perkin medal, W. R. Whitney, industrial research.

CONTEMPORARY EVENTS

Recognition of Irish Free State.

Washington Conference on Limitation of Armaments (Nov.-Feb. 1922): Naval limitation treaty signed by U. S., Great Britain, France, Italy, and Japan.

1922

TECHNICAL-SCIENTIFIC

Mallinckrodt began manufacture of analytical reagents.

Vitamin E reported by H. M. Evans and K. S. Bishop.

Lead tetraethyl as anti-knock, Thomas Midgley, Jr.

Switch of fertilizer industry from pyrites to brimstone as acid raw material completed; standard fertilizer formulas adopted by manufacturers and agricultural colleges.

Furfural from farm wastes investigated by Agriculture Dept.; furfural resins patents by Durite Plastics (E. E. Novotny).

Calcium arsenate from iron arsenate ore, F. K. Cameron process, Salt Lake Insecticide Co.

Oxidation-reduction potentials studied, J. B. Conant.

Chromium plating developed, C. G. Fink.

Electrodeposition of rubber patented (Sheppard & Eberlin), Eastman Kodak Co.

Continuous cracking of high throughput in petroleum refining.

Becker-type coke ovens installed, Chicago.

U. S. Public Health Service officially recognized 5 arsenical antisyphilitics.

American Institute of Chemists founded.

CONTEMPORARY EVENTS

League of Nations Council met in Geneva.

End of British protectorate over Egypt; Balfour Note pledging support of a free Palestine; Lloyd George resigned.

Assassination of Rathenau and great political confusion in Germany.

France and Japan signed the Washington Disarmament Treaty.

Coal and railway strikes delayed industrial recovery.

U. S. Federal Child Labor Law declared unconstitutional.

Shantung Agreement.

Allied Reparations Council denied Germany moratorium, but relieved her of cash payments in 1922.

Settlement with Great Britain of dispute over the Mesopotamian oil fields.

Turkey defeated Greece; armistice signed.

1922 (*Continued*)

GENERAL

Federal Trade Commission investigated calcium arsenate insecticides.

American Chemical Society membership reached 14,400; largest chemical association in world.

Chemical Guide Book, first annual edition.

INDUSTRIAL-COMMERCIAL

First commercial deposit of colemanite (Nevada) worked outside of California.

Seydel Manufacturing Co. became Seydel Chemical Co.

Fort Worth helium plant in continuous production.

1922 (*Continued*)

TECHNICAL-SCIENTIFIC

Chandler medal, E. F. Smith, "Samuel Latham Mitchell."

Grasselli medal, W. H. Fulwiler, "Chemical Problems in the Gas Industry."

Perkin medal, W. M. Burton, petroleum cracking.

CONTEMPORARY EVENTS

"Stevenson Plan" to control British rubber exports from plantations in effect (Nov. 1).

Fascists in control of northern Italy; Mussolini asked to form Cabinet.

Japanese denied U. S. citizenship.

PART ONE

SETTING OF WORLD WAR I PERIOD

Chapter 1

THE WILSONIAN BACKGROUND

A. D. LITTLE'S PROPHECY—FAMILY-OWNED STATUS OF THE INDUSTRY—WILSON'S LIBERAL LEGISLATION: FEDERAL RESERVE, CLAYTON, AND REVISED PURE FOOD ACTS—HOWARD PLEADS FOR LOGICAL CHEMICAL RATES IN UNDERWOOD TARIFF—HEARINGS UNCOVER RUTHLESS GERMAN COMPETITION.

ON THE EVENING of September 11, 1913, an exceedingly clever, highly cultivated chemical engineer rose at a banquet table in Rochester, New York, and delivered this remarkable prophecy:

> Germany, long recognized as preeminently the country of organized research, is now being threatened by a new competitor, challenged in industrial research, strangely enough, by the United States, that prodigal among nations, still justly stigmatized as the most wasteful, careless, and improvident of all. For while most of the industrial efforts in this country still proceed with a happy disregard of basic principles—alike of chemistry and of engineering—yet among our manufacturers many are learning that efficiency of production is a sounder basis for prosperity than the mere value of product, however great, and that the most profitable output of their plant is that which results from the catalysis of raw materials by brains. The catalysis of raw material by brains: that is applied chemical research.

In this brilliant presidential address to the American Chemical Society, Arthur D. Little pointed out what few men then recognized. He perceived that the exalted position Germany then occupied in the chemical world rested not upon distinguished discoveries in pure science, but upon the solid commercial basis of ceaseless applied research. As chemical engineering consultant to many companies in various fields, Little felt the first slight stirrings of the research movement in the American industry. A pioneer in such consulting work and a consummate salesman of chemical ideas, he rendered distinguished services in the fields of paper-making, rayon, cellulose acetate, chrome-tanning, lacquers, and petroleum solvents at a critical stage in the industrial development of these chemical operations in the United States. He sensed the growing employment of chemical processes in many other industries and appraised correctly the big demand for chemical products which this development would create. Knowing our enormous output of standard inorganic chemicals—even at that time greater than the combined output of Great Britain and Germany—and appreciating our flair for large-scale manufacturing technique, he foresaw clearly the vast potentialities of the chemical industry in this country. What Little did not see, of course, was the coming of the World War which within the year was to make his bold prophecy come true with startling suddenness.*

That war was to reveal in a flash, like a star shell bursting over No Man's Land, the key position which chemicals had come almost unwittingly to occupy in the modern industrial economy. But that evening, hardly one among the two hundred-odd chemists who listened to Dr. Little's telling phrases realized what chemistry and chemicals had come to mean. None of them guessed that a twelve-month hence they would all be thrown into a tremendous new effort. They were to learn that modern war not only commandeers all chemical supplies, but also commands all chemical activities.

So tyrannically did that war dominate the American chemical scene between 1914-18, and with such important results, that we are apt to forget other influences that had notable effects. The industrial situation was then very different from that with which we are now familiar. Yet within it there arose certain political and social forces which were subtly to shape the ends of the American chemical industry of the 1940's quite as much as did the rough upheaval of the First World War itself.

At that time, our chemical industry was comparatively small and quite simple in its organization. Thanks to its protective tradition of secretiveness, it was notably inconspicuous. Although during the first decade of the century the value of American chemical output had shown a lusty increase from sixty-two to one hundred and seventeen million dollars,† nevertheless, by no flight of the imagination could the

---

* Born in Boston, Dec. 15, 1863, Little studied at the Mass. Inst. Tech. for 3 years and at 23 launched upon his career as junior partner in the consulting firm of Griffin & Little (1886-93). He branched out for himself till 1900, when he formed a new partnership with William H. Walker (Little & Walker, 1900-5). In 1909 he headed Arthur D. Little, Inc., which firm built in Cambridge what was then the largest, best-equipped private consulting laboratory building in the country. He was pres. of the Am. Chem. Soc. (1912-14), the Am. Inst. Chem. Engrs. (1919), the Soc. Chem. Ind. (1928-29) and in 1918 was awarded an hon. D. Chem. by U. Pittsburgh. A life member of the Corp. of the Mass. Inst. Tech., he willed his consulting business to that institution. He died Aug. 1, 1935. (See also *Chem. Ind.* *37*, 161 (1935); Haynes, *This Chemical Age*, p. 292.)

† U. S. Census figures: *1900*—value of products, $62,700,000; capital, $89,100,000; number of employees, 21,200; wages and salaries, $12,100,000. *1910*—products, $117,700,000; capital, $155,100,000; employees, 27,600; wages, $20,300,000. [See also *Chem. Met. Eng.* *19*, 364 (1918).]

manufacture of chemicals in this country then be characterized as "big business."

Most of the plants were still family-owned. Generally the business was vigorously administered by the founder or his sons. True, Dr. William H. Nichols had gathered together twelve producers of sulfuric acid into the General Chemical Company,[1] and William Hamlin Childs had combined a number of small refiners of coal-tar products into the Barrett Company.[2] However, both these early consolidations were still dominated by their moving spirits, and the stock, though publicly traded in on the Exchange, remained largely in the hands of those who had owned the merged companies. Then but two chemical companies had financial roots that grew in the direction of Wall Street. Frank S. Washburn with experience and backing from the hydroelectric utilities had organized the American Cyanamid Company. Under inspiration from the tax-free Alcohol Law, the United States Industrial Alcohol Company had been formed by a group of distillers and bankers.

Only in the fertilizer field did the strong merger movement of the eighties and nineties make appreciable headway. By the then-typical methods of consolidation, the Virginia-Carolina Chemical Company, the International Agricultural Corporation, and the American Agricultural Chemical Company had all been put together. These mergers were inspired by the fears of too-keen competition and the hopes of stabilizing prices, which were characteristic of this period. Nevertheless, the problems of the fertilizer makers were quite distinct from those that the chemical manufacturers faced. Although some fertilizer companies made substantial quantities of trisodium phosphate and many sold their excess sulfuric acid, nevertheless, generally speaking, neither the methods nor the markets of the two groups were related. The fertilizer and chemical leaders of that day certainly did not identify themselves in any way with their common interests.

These fertilizer consolidations, therefore, had little effect upon the chemical industry which passed serenely through the trust-building era and Theodore Roosevelt's trust-busting days virtually untouched by these significant incidents in American industrial development. Later, in the postwar period, when the consolidation movement did reach the chemical industry, its force and direction had been changed. The "trusts" of the eighties and the "holding companies" of the nineties became the "mergers" of the twenties. This was much more than a mere change of words.

The earlier consolidations in the steel, tin plate, lead, glass, salt, tobacco, sugar, cottonseed oil, and a score of other fields, brought together warring competitors. Their purpose was to end bitter, intra-industry battles by the simple absorption process of eliminating competition. Their aims were frankly, even boastfully, monopolistic. Despite the formidable front which they presented, the trusts of the nineties were essentially defense mechanisms. The few scattered, prewar chemical consolidations were obviously built up upon this model. Destructive competition prompted the formation of the three big fertilizer companies and of the Barrett amalgamation of coal-tar refiners.

In the case of the General Chemical Company, however, the defense was against a competitive factor distinctive to chemical manufacture—the threat of a revolutionary technological improvement. In England the United Alkali Company had been the reply of the Leblanc operators to the menace of ruinous competition from the new Solvay process. Similarly in this country, the ominous competition of the Badische contact process forced a number of American sulfuric acid makers to join forces more or less unwillingly. Indeed, were it not for this impelling incentive, it is doubtful whether Dr. Nichols, for all his skill and leadership, could have banded these bitter rivals together.

After the passing of the Clayton Act, signed by Woodrow Wilson on October 15, 1914, such consolidations of direct competitors became legally impractical. This law, one of the important points in Wilson's legislative program of reform, was definitely designed to strengthen the old Sherman Anti-Trust Act. Further buttressed by the creation of the Federal Trade Commission five months later, this legislation maintained and emphasized the Government's policy of opposition to industrial combinations in any form. Now, for the first time, there was a well-rounded program of official activity to implement this policy not only by disbanding existing trusts, but also by blocking the formation of new ones. Finally, these laws created effective machinery for carrying out this program.

This hostile but carefully considered plan to curb the big corporations was abruptly interrupted by the war, and when peace was restored the entire situation had radically changed. The attitude both of the courts and of the people towards big business had been softened, and while the motives of consolidation remained the same—greater strength and more profits—nevertheless the method of achieving these ends had been revised. Instead of binding closely together a group of warring competitors, the postwar consolidations sought strength through vertical expansion. They reached backward to control over raw materials and forward to distribution of goods to the ultimate consumer.

In the chemical industry the individual companies had enormously expanded during the war. The merger movement thus became a sharp spur to the further diversification of products. Under these circumstances, an American chemical trust, comparable in any way to the

BERNARD M. BARUCH

LELAND L. SUMMERS

CHARLES H. MacDOWELL

MARCH F. CHASE

dominating I.G. Farbenindustrie in Germany or the inclusive Imperial Chemical Industries in England, had become unthinkable. Both these foreign chemical giants had expanded horizontally and vertically to an all-embracing position. In the United States no such inclusively monopolistic, "alum-to-zinc" corporation was possible.

Before the war in Europe diverted his attention from domestic affairs, Woodrow Wilson's administration, firmly led by him, enacted the most remarkable body of social and economic laws which had been passed since the Civil War. Hardly had the President settled in the White House, before he called a special session of Congress which he addressed in person, April 7, 1913:

"We are to deal with the facts of our own day, with the facts of no other, and to make laws that square with these facts."

He then proceeded to interpret the facts as he saw them and to sketch a broad legislative program. With a House of Representatives two-thirds Democrat, and a majority of six in the Senate strengthened by one Progressive and a few insurgent Republicans, a Democratic President had for the first time since the Civil War a working majority in both Houses of Congress to carry out his party platform. Technically, that is from the party point of view, this control was due not to a majority vote of the electorate, but to the Taft-Roosevelt split among the Republicans. Nevertheless, Wilson's liberal program did have the approval of most of the American people.

Taft, having received his renomination from the Republican party machine, had run in the triangular campaign on an avowedly conservative platform. Theodore Roosevelt, having bolted the Republican convention and carried with him the progressive wing, crusaded for the "New Nationalism," advocating federal regulation of trusts, direct primaries, the recall of judicial decisions, liberal labor legislation, and a federal income tax. Wilson was nominated with the open support of William Jennings Bryan on the forty-sixth ballot of a Democratic convention that had started out in conservative rebellion against Bryan's leadership.[3] During the campaign, Wilson preached the "New Freedom," promising, in very general terms, to restore the lower middle class, the workers and the farmers, to a place of authority in Washington. There was no doubt that like Roosevelt, Wilson stood squarely with the liberals. As Governor of New Jersey he had openly defied the reactionary party bosses of the State. He personally secured the passage of laws authorizing the direct primary, providing for workingmen's compensation, and regulating the public utilities.

Accordingly, that legislative program which Wilson laid before Congress with all his famous rhetorical skill was in the main but a summary of reform measures, most of which had been proposed before 1900 and a number of which could not be reconciled with the traditional principles of the Democratic party. It was, nevertheless, an impressive program. Despite the distraction of the war, he fulfilled —indeed more than fulfilled—his campaign pledges.

In December 1913, the Federal Reserve Act was passed. It had been drafted by President Wilson, William G. McAdoo, his Secretary of the Treasury, Senator Robert L. Owen, and Representative Carter Glass. Most of its technical banking details were borrowed, however, from the plan of the ultraconservative Senator Aldrich of Rhode Island. Curiously for a Democratic law, it provided for greater centralized government control than the Republican bill. Ten months later the Clayton Act put some suggestively Republican teeth into the Anti-Trust Law. Within the year there were enacted an eight-hour day for trainmen, the Farm Loan Bank, a national Child Labor Law (which was later declared unconstitutional), and, of particular interest to the chemical industry, a drastic strengthening of the administration of the Pure Food and Drugs Act and the Harrison Act controlling the sale of narcotics.

The Democratic platform upon which Woodrow Wilson had been elected President contained but one important plank that differed in essence from the pledges of the "Bull Moose" party. Roosevelt's tariff plank expressed belief "in a protective tariff which shall equalize conditions of competition between United States and foreign countries, both for the farmer and the manufacturer, and which shall maintain for labor an adequate standard of living." While it promised revision, it indicated clearly that the new rates would be written in strict accord with these Hamiltonian principles.

Wilson's tariff plank, on the other hand, bluntly declared that any tariff except for revenue was unconstitutional. Though it mollified this ultimatum by assurances that revision to a purely revenue base would be gradual and give industry ample opportunity for readjustment, nevertheless, it promised unequivocally that the revision would be sharply downward.

The most distinctively Wilsonian and Democratic measure passed before the outbreak of the war, therefore, was the Tariff of 1913, commonly known as the Underwood Tariff Act from its sponsor, Oscar W. Underwood of Alabama, chairman of the House Ways and Means Committee. Tariff revision had been a live political issue for several years. It was on the tariff that the Democrats had differed most sharply from the Progressives in the three-cornered election of 1912. Stimulated by the widespread, popular agitation against the big corporations of the trust-building era, a good deal of sentiment had been roused, especially among farmers and workers, for lower tariff rates. Theodore Roosevelt had openly advocated revision downward, and when Taft was nominated and elected more or less admittedly as his political heir, the country believed that the Payne-Aldrich Tariff of 1909, passed early in Taft's administration, would lower the rates. On the contrary, the Republican majority in Congress materially raised the schedules of the Dingley Tariff of 1897. New duties were imposed on coal, iron, and hides. The schedules for lumber, cotton, and all important textiles were materially increased.

In the face of these advances, virtually all chemical duties had been reduced, some of them markedly. President Taft was inclined towards a lower tariff, but he was peculiarly susceptible to the old "for-the-good-of-the-party" plea urged upon him by his most trusted political advisors. Nevertheless, he did not surrender unconditionally. Taft had introduced into Congress and passed under pressure a reciprocity agreement with Canada, providing for free trade on certain food products and lower rates on other foodstuffs and a number of manufactured goods. Their grain markets threatened, the Middle-Western farmers raised a gale of protest, and in attempting to win them over, Democratic Senator Champ Clark of Missouri and the President, himself, let slip some exceedingly foolish, ill-timed remarks about the possible future annexation of the Dominion. Even the hint of such a proposal so roused the Canadians that they overwhelmingly repudiated the proposed treaty in a popular election.

Resentment over the higher duties of the Payne Tariff helped the Democrats to win control of the House of Representatives and to pare down the Republican majority in the Senate so thin, that with the votes of a few insurgent, progressive Republicans, the Democrats had practical control of both Houses of Congress. Accordingly, in 1911 a number of tariff bills were introduced, not so much in hope of their passage, but in order that they might keep the issue before the country for the coming presidential election. High textile schedules were an easy target for attack and among these bills was the Cotton Schedule Bill reducing the tariff on all cotton manufactured goods. As a sop to Southern cotton manufacturers, a horizontal reduction of from 15 to 25 per cent on all chemical rates was tacked onto this bill.[4] This clumsy, heavy-handed treatment of the complicated chemical schedule provided Taft with an excellent, logical reason to veto the Cotton Bill.[5]

Without a moment's delay, Woodrow Wilson plunged into the thick of this tangled tariff situation. Breaking with precedent, he appeared in person before Congress and delivered a fighting message which made it plain that he wanted a tariff for revenue only. He pointedly warned the Democrats against the blandishments of the professional lobbyists who at the time swarmed in Washington. By this single, bold stroke, he assumed active command of his party in the legislative halls as well as in the executive offices, and dealt a telling blow to the most skilled, powerful enemies of tariff reduction. So firmly did he establish his party leadership, that he kept the legislators hard at work on the irksome task of tariff revision during the hot Washington summer. So thoroughly did he castigate the lobbyists, that for the first time in three-quarters of a century these "agents of the invisible government of the special interests" took to cover, their influence in rate-writing practically nullified.

In the famous red-plush, carved-oak conference room, hearings on Schedule A—covering chemicals, dyes, drugs, medicines, oils, paints, varnishes, etc.—began January 6, 1913, before the House Ways and Means Committee. As a definite working basis, the Committee set up for reconsideration the hastily drawn schedules of the year before.[6] Most of the testimony to which it listened pointed out inconsistencies and injustices due to ignorance of chemical processes and scant consideration of the relationship of raw materials to finished products and by-products.

The first witness was the experienced chief-operating executive of the Merrimac Chemical Company, Henry Howard,* who spoke on behalf of the Manufacturing Chemists' Association. With considerable tact, he pointed out that Schedule A had been crudely drawn because the production of chemicals is a complex business dependent upon reactions and processes difficult for the layman to understand. As a result, the proposed reclassification was illogical, frequently imposing higher duties on what were essentially raw materials while at the same time radically reducing the rates on finished products. The new duties would seriously, in some cases critically, handicap American manufacturers competing with European chemical makers who were commonly organized into various cartels, selling syndicates, and trusts—all powerful, aggressive forms of consolidation forbidden to American chemical companies by law.

Howard proposed, therefore, that the Ways and Means Committee appoint a subcommittee empowered to engage its own expert chemical advisors, who would study very carefully the ramifications of the chemical schedule. He offered the services of all members of the Manufacturing Chemists' Association to assist in any way in clarifying

---

* Upon graduation from Mass. Inst. Tech. in 1889, Henry Howard had joined the Merrimac staff and had succeeded his own father, Alonzo P. Howard, as vice-pres. in charge of production. Later (1920-26) he became dir. of research of the Grasselli Chemical Co. He served the Mfg. Chem. Assoc. as chairman of the Exec. Comm. (1904-26) and as pres. (1926-28), and was pres. of the Am. Inst. Chem. Engrs. and the Am. Electrochem. Soc.

J. LEONARD REPLOGLE

EDWIN B. PARKER

RICHARD L. WOOD

CHARLES E. SHOLES

technical or commercial problems, so that fair and equitable rates might be determined.[7]

The logic of Howard's quiet-spoken arguments appealed to several members of the Committee, but time pressed. No congressman wanted to become involved in the highly technical details of a scientifically drawn chemical schedule. Such a tariff would be obviously to the advantage of the manufacturers. Their official offer of cooperation was made in good faith, but it was naturally suspect. After the President's spirited attack upon the representatives of all trade and industrial organizations, it was quite impossible for the Democratic majority of the Committee to agree to any such proposal.

Witness after witness cited specific instances of chemical raw materials, previously on the free list, that were now being made dutiable, while at the same time lower rates were being proposed on finished products made from identical raw materials. It was proposed, for example, to take from the free list all the coal-tar raw materials in Paragraphs 23 and 24 and place a duty of 5 per cent on the former and 10 per cent on the latter section.[8] A joint statement signed by Edward Mallinckrodt, Jr., A. G. Rosengarten, John F. Queeny, John Anderson, Donald McKesson, Otto Schaefer, and E. W. Preston,[9] pointed out that, thanks to domestic competition, vanillin, which formerly sold for $5 an ounce, was now selling for 35¢. The current duty of 20¢ had already been reduced from 80¢ in the Payne Tariff. The proposed bill cut the vanillin duty to 10¢, but at the same time removed from the free list three of its important raw materials: cloves dutiable at 2¢ a pound; caustic potash, ⅗¢; and benzene, 5¢. In other words, the rate on the finished organic chemical was to be cut 50 per cent, but of the duties on six chief raw materials it was proposed to take three off the free list and raise the duty on two others.[10]

Summarizing, Henry Howard analyzed the changes proposed on 300 specific chemical items of which 97 (roughly a third) were raw materials and the rest finished products. Of the 97 raw materials, 80 were free under the Payne Act of 1909 and duties were increased on practically all the 17 others. The revenue from the finished chemicals under the Act of 1909 had been $1,826,955, while the estimated revenue from their raw materials under the proposed rates would be $6,081,060, an increase of approximately $4,000,000.[11] As the brief of Merck & Company concluded: "Your Honorable Chairman is reported to have stated: 'To reach this result I prefer to lower the tariff by taking bricks off the top of the wall rather than by dynamiting the structure from the bottom.' We would respectfully express our conviction that the assessment of duty on such raw materials now being supplied to manufacturers free of duty, is applying dynamite to the bottom of the structure." [12]

This reversal of the historic policy of admitting raw materials free was prompted by the knowledge that a radical reduction of rates on finished products would materially reduce tariff income. Tariff revenue from the finished products in Schedule A had been $11,139,590, while under the proposed law it would be $10,089,097. Higher duties on raw materials would more than offset this loss by a net gain of nearly $3,500,000 from the entire chemical group. These higher duties on raw materials were justified by a curious political reasoning which Representative Burton Harrison of New York expressed as follows: "Is it not true if a reduction is made on the duties upon the finished products, it would be difficult, if not impossible, for the American manufacturer to hand on that tax on his raw materials? In other words, it would be difficult for him to increase the price to the consumer if the duty were lowered upon his finished product." [13]

In view of the desperate dye crisis which the country was to face within eighteen months, one of the most interesting witnesses at these hearings was J. F. Schoellkopf, Jr.,[14] head of the largest American dye-making company. He painstakingly sketched the plight of the American manufacturers of coal-tar chemicals. In spite of the fact that they were facing increasingly centralized, ruthless competition from the German Dye Cartel, their tariff protection had been constantly whittled down. Schoellkopf tried patiently to explain some of the chemical and commercial intricacies of making finished colors out of imported intermediates. Chairman Underwood, who betrayed his political interest in cheaper dyes to compensate the influential textile industries for drastic cuts on their finished products, handled this witness roughly. He affected to believe that the manufacture of dyes was simply a mixing process involving neither very great skill nor much labor. "Of course," he said, "chemical changes take place, but I am talking about a mechanical proposition as far as labor and time are concerned. After all, this appears to be just a question of mixing them together." [15]

Claude Kitchin joined in this ragging and two Republicans, Ebenezer Hill of Connecticut and Nicholas Longworth of Ohio, who both later proved to be good friends of the American dye industry, came to Schoellkopf's rescue. But it is exceedingly significant that in all the testimony on coal-tar dyes at these hearings in 1913, not a word was said about the key position these chemicals occupied as commercial bases of coal-tar medicines, colors, high-power explosives, and poison gases.

Much plain-spoken testimony revealed, however, the unscrupulous competition of foreign, particularly German, manufacturers. Dr. S.

Lewis Summers told the scandalous story of aspirin sold here for 43¢ an ounce and throughout the rest of the world for 10¢.[16] William A. White testified to the cutthroat competition in pyrogallic acid which the Eastern Chemical Company met from German makers, who had lowered the price from $1.04 a pound in 1889 to 64¢ in 1912 to discourage American production.[17] The bankruptcy of the American Alkali & Acid Company of Bradford, Pennsylvania, in 1908, due to ruthless price-cutting on oxalic acid—9¢ in 1903; 5¢ in 1906—was set forth in detail.[18]

Schedule A was finally adopted on April 29, 1913. Few changes were made as a result of the hearings, and the Underwood Tariff Bill passed the House May 8, by a straight party vote of 281 to 139, four Democrats voting against and only two Republicans for it.[19] It was immediately sent to the Senate Finance Committee [20] which reported it out favorably on July 11, after making comparatively few revisions in the chemical schedule. The principal shifts were downwards. Alizarin and alizarin colors, sodium phosphate, and potassium cyanide were added to the free list and reductions were made in the rates on oxalic acid. Higher duties were placed on collodion, cellulose products, and lead and zinc ores. After two months of vigorous debate, the bill was adopted in the Senate, again by a straight party vote of 44 to 37.[21]

From the point of view of the chemical industry, the final draft was even less favorable than the original House proposal. It ignored even more flagrantly the relationship of raw materials to finished products, but it passed the House on September 30, the Senate on October 3, and was signed at nine o'clock that night by President Wilson to become effective the next day, October 4, 1913.[22]

Although the new tariff was frankly partisan, nevertheless it did express the widespread revolt against the high Payne duties of 1909 and the growing popular conviction that protection was a shield for the big trusts rather than a buckler for infant industries. Its rates revealed all the weaknesses implicit in the haste and political pressure under which they had been written.[23] Notably this was true of Schedule A. Too little time and very little pains were taken to master the complexities of chemical making and marketing. But nobody in Congress then comprehended the vital importance of chemicals to all industrial activity, to national defense; and the chemical makers were in this respect but little wiser than the lawmakers.

For better or worse the Underwood Tariff never had a fair trial. Initially its effects upon general business conditions were badly depressing. Obviously it would have retarded the growth of chemical manufacturing in this country. It might well have completely wiped out the struggling coal-tar branches of the industry. Eventually, even upon a revenue-only basis, many of its rates would have had to be revised. It is futile, however, to speculate about the ultimate effects of a consistent, lower-tariff policy upon American industrial development, especially our chemical development, since ten months after the Underwood rates became law they were virtually nullified by the outbreak of war in Europe.[24] Abnormal conditions completely canceled their effects and created fresh, impelling impulses to chemical growth along new lines.

REFERENCES

1. *The General Chemical Company After Twenty Years.*
2. Haynes, *Chemical Economics*, p. 265.
3. Hibben, *The Peerless Leader*, pp. 294-318; Seymour, *Intimate Papers of Colonel House*, I, pp. 48-55; Tumulty, *Woodrow Wilson as I Know Him*, pp. 118-24.
4. *O.P.D. Reptr.* 9 (Aug. 21, 1911).
5. *Ibid.* 9 (Sept. 4, 1911). For good summary of these tariff matters from the chemical point of view, see *ibid. Ann. Rev.* Pt. 2, p. 3 (Mar. 10, 1913); also Shannon, *Economic History of People of United States*, p. 782; Jennings, *History of Economic and Social Progress of the American People*, p. 369; De Witt, *Progressive Movement*, and the leading text on the subject, Taussig, *Tariff History of United States.* Tariff rates are in Appendix V.
6. H.R. 20,182; see also *O.P.D. Reptr.* 7, 9, 28F. (Feb. 19, 1912).
7. Hearings Ways & Means Comm. (House 62:3) on Tariff Schedules, I, pp. 1-5 (1913).
8. *Ibid.* p. 71.
9. *Ibid.* p. 46.
10. *Ibid.* p. 71.
11. *Ibid.* p. 4.
12. *Ibid.* p. 29.
13. *Ibid.* p. 159.
14. *Ibid.* p. 134.
15. *Ibid.* p. 140.
16. *Ibid.* p. 9.
17. *Ibid.* p. 31.
18. *Ibid.* p. 56.
19. *O.P.D. Reptr.* 34 (May 5, 1913).
20. Briefs and Statements on H.R. 3321, I.
21. *O.P.D. Reptr.* 32L (Oct. 6, 1913).
22. *Ibid.* For current comment on Underwood Tariff, see Tariff Commissioner's *Ann. Rept. 1916-17*, 12; *Pharm. Era 96*, 318 (June 1913).
23. Smith, *Economic Planning and Tariff*, p. 94.
24. Taussig, *op. cit.* pp. 361-400.

Chapter 2

TARIFF DEPRESSION TO WAR BOOM

UNDERWOOD TARIFF ACCELERATES BUSINESS SLUMP—WAR DEMANDS FOR ALL CHEMICALS GROSSLY UNDERESTIMATED—INTRODUCTION OF SMOKELESS POWDER AND COAL-TAR DISRUPTANTS CREATES NEW NEED FOR PHENOL, TOLUENE, AND NITRIC ACID.

BUSINESSMEN, especially manufacturers, had been profoundly upset by the election of Woodrow Wilson. For years the Republican party had made political capital out of "good times," and it had come to be almost an American tradition that a Democratic regime in Washington meant a panic for the rest of the country. In accord with another good old American political custom, the election year of 1912 had been marked by a falling off in general business. This was interpreted as most ominous. The decline had come despite bumper crops of cotton, wheat, corn, and hay, and so long as the country was predominantly agricultural in its activities and our farm surplus was being shipped abroad, big crops, particularly of wheat, cotton, and meat, virtually underwrote prosperity for the nation.

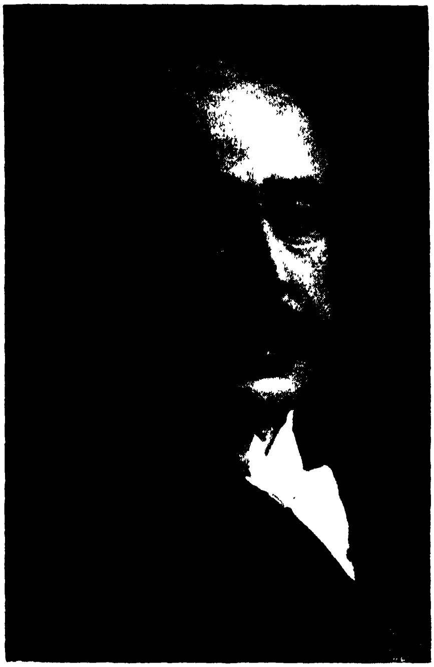
The year 1913 saw the country internally disturbed by heavy floods and by serious strikes in the coal and railway industries. International events were foreboding—a revolution in Mexico and war in the Balkans—but more directly our export trade was suffering from the tense competition between Great Britain and Germany for the markets of South America, and from England's active, initial encouragement of closer economic cooperation within her empire. The reciprocal trade treaty between Canada and the British West Indies was disconcerting. This promised to reduce our sales to Canada and practically to eliminate us from the Caribbean market for meat, grain, and dairy products. The Cassandras had plenty of omens from which to prophesy industrial desolation.

The chief worry of business leaders was, however, the new President himself. He was a Democrat, which was bad; a progressive Democrat, which was worse; a progressive Democrat and college professor of long standing, which was much more than enough to send shivers of distrust racing up and down the spine of any practical industrialist. Most of these rugged individualists of the Gay Nineties had battled their way up through the ranks. All of them had at their fingertips every detail of their business. Having themselves learned by doing, practical experience was to them the invaluable equipment for success. Most of them regarded anything that even smacked of theory with suspicion.

On top of all his personal disqualifications, Wilson had a working Democratic majority in Congress, and the masterful fashion in which he had held the legislators to their task of passing the partisan Underwood Tariff showed plainly that this starry-eyed dreamer, as they regarded him, was an energetic, successful party leader. His record as Governor of New Jersey confirmed all these fears, and it was quite easy for business leaders to foresee a wild flood of laws inimical to the established interests, which would drown prosperity.

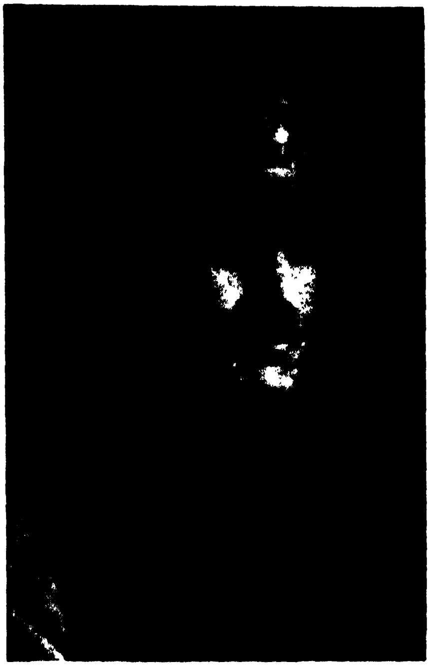
This dismal diagnosis of the situation proved discouragingly sound. Business, which had been good during the earlier months of 1912, began to fall off in the autumn.[1] Commodity prices, notably the prices of industrial raw materials, began to decline. This had commonly been observed to be a symptom of the early stages of a depression.[2] Following the passage of the Underwood Tariff Act, business conditions degenerated sharply, and when war broke out in Europe in August 1914, the country was fairly launched upon the economic downswing.[3] Thus the United States was plunged into a world-war economy at the very moment when its industrial and financial machinery was sputtering and threatening to stall. This was a unique experience. The outbreak of both our Civil and Spanish Wars had come at a time when the nation was climbing the upswing of the business cycle.[4]

The immediate outward and visible sign of this baneful combination was a panic on the New York Stock Exchange. Due to the pessimistic conservatism generated by the prospects of a lower tariff and the then-novel economic and social laws sponsored by Wilson, the American stock market had been wallowing in the doldrums for over a year. Confidence, if shaky, had been just sufficient to prevent any serious decline of security values, but with what appeared to be the collapse of our civilization, this timid confidence vanished. When, on the morning of July 31, 1914, the London Stock Exchange suspended, leaving New York the sole free, open security market on earth to absorb the full shock of a world-wide panic, the only possible action was to stop trading. For the second time in over a century the New York Stock Exchange closed its doors.[5] To Wall Street this was the end of the world. A number of very responsible gentlemen permitted themselves to be quoted to the effect that the cost of a general European war would bankrupt the world; that all property was in jeopardy; that there was not enough money on earth to run the war six months; that civilization was doomed. Yet within six months, on December 15 to



MARSTON T. BOGERT

WILLIS R. WHITNEY



SAMUEL A. TUCKER

HERBERT R. MOODY

be exact, the New York Stock Exchange reopened. Within another six months confidence had so returned that shrewd bargain hunters began accumulating high-grade securities whose prices had been forced to an abnormal low, due to the unloading on this market of American shares previously held abroad.

In view of this flood of foreign-owned securities which we had to absorb, the stock market debacle is quite understandable. It is not so easy to comprehend, however, why the sudden outbreak of war should have sent chemical prices spinning downwards. Seemingly little perspicacity should be needed to anticipate the enormous demands that a big European war would make upon American chemical supplies. True, at that time, not even the German High Command appreciated the vast amounts of benzene and toluene, of ammonia, of sulfuric and nitric acids, of caustic soda and soda ash, of chlorine and bromine needed in modern, large-scale warfare. While the Kaiser's armies were marching through Belgium, no one in this country dreamed that American chemical plants would be called upon not only to munition the Allies, but also in a great measure to furnish the neutral world with chemicals formerly bought from Great Britain and Germany.

Even if the extent and length of the war were quite unsuspected and its chemical demands woefully underestimated, we had plenty of precedents, and good reason, too, to remember that war requires ammunition and medical supplies, which greatly increase chemical consumption. American chemical manufacturers knew these facts, but they could not then see why the older, well-organized, diversified chemical industries of England and Germany, both producing an exportable surplus of many chemicals, should not be able to take care of all their own war requirements. Our chemical industrialists had reason to be concerned about the domestic situation and they spent many a sleepless night during that hot, muggy August of 1914, speculating upon the course of the war and the future of American chemical business. Each morning they found their desks piled high with postponements and cancellations of shipping instructions from their regular contract customers. As deliveries slowed down and inventories began to pile up, their nervousness grew. Not all of them had the patience and courage to reply as Edward Mallinckrodt, Sr., did. When his youthful assistant, Fred Russe, urged that since there was sufficient stock for several months, they should close the plant and keep only a skeleton force at work, Mallinckrodt said: "Things are pretty bad in St. Louis, and if we discharge several hundred of our people, that would cause a good deal of hardship, even suffering in some cases; but if we keep them all at work, I am the only one who is hurt. Remember, too, that just as we don't have good times all the time, so we won't have bad times forever. Before long, we shall be able to sell all the stocks that we are now making up." [6]

Within the year those threatening surplus stocks had vanished and the bins were being scraped to fill war orders for all sorts of fine and medicinal chemicals. Every chemical manufacturer in the country was oversold. War had stopped the decline and transformed it into a boom.

In the first violent dislocation of ocean shipping at the outbreak of the war, when the British cruisers were scouring the seas to pick up enemy merchantmen, exports from Atlantic ports virtually ceased. Hardest hit of all our chemical products were rosin and turpentine, acetate of lime and methyl alcohol.[7] By a stroke of poetic justice the first cabled inquiries from the other side were for naval stores and wood chemicals. These were soon followed by frantic demands for phenol and acetone. By late autumn British and French agents began arriving in New York, their portfolios filled with long lists of sorely wanted supplies. At the head of those lists stood phenol for the production of picric acid (trinitrophenol) and acetone as solvent-stabilizer for the British cordite. To the critical demand for these chemicals was later added toluene and fixed nitrogen. About this quartet was centered most of the World War chemical effort. The Allied armies were chronically short of explosives.

Since Roosevelt and his Rough Riders had charged up San Juan Hill, an interesting, and from the chemical point of view an exceedingly significant, revolution had taken place in military explosives. American and Spanish armies were both munitioned with black powder, the same old saltpeter-sulfur-charcoal mixture which the Moors are said to have stolen from the Chinese and with which they conquered Spain during the twelfth century. Sportsmen had already discovered the advantages of smokeless powder—greater hitting power, less fouling of gun barrels, elimination of telltale clouds of smoke—so that the disadvantages of black powder became painfully apparent by comparison, especially in the guerrilla warfare in the Philippine jungle. Black powder passed definitely out of military history with the Spanish-American War.[8]

The British in South Africa fought with cordite, based upon Alfred Nobel's discovery of the gelatinization of nitrocellulose in nitroglycerin. This reaction was originally accomplished by heating, but to reduce the extreme hazards, a cold gelatinization process with acetone as a solvent was perfected. The cordite of the Boer War contained 58 per cent nitroglycerin, 37 per cent nitrocellulose, and 5 per cent petrolatum as a retarding agent.[9] The British ordnance experts continued to experiment with this cordite of theirs and by 1914 had settled upon the formula of 30 per cent nitroglycerin and 65 per cent nitrocellulose.[10] This larger percentage of nitrocellulose required much greater quantities of acetone, and when we remember that during the war, production of British factories was 139,000 tons of cordite,[11] the magnitude and seriousness of the acetone problem are plain.[12]

During the Boer War an absolutely new type of explosive was introduced, the disruptives, sufficiently stable to withstand the shock of the propellant in the discharge from the gun and so usable as a bursting charge for the projectile. In the latter phases of that war (1899-1902) the English enormously increased the effectiveness of their artillery by providing them with bursting shells loaded with a mysterious material. This was named lyddite, after their artillery proving grounds at Lyde in Kent.

In these days of superespionage, military secrets are not kept long. Those who first learn them, however, seldom publicly record their discoveries, so priority of discovery is commonly obscure. Accordingly, it is not altogether clear whether the French perfected their melinite before the British did their lyddite. Shortly afterward the Japanese came along with a disruptive explosive, shimosite. Soon everyone in military and chemical circles whose business it was to know about such matters had learned that lyddite, melinite, and shimosite were all essentially picric acid.

Picric acid itself was nothing new. It had been first prepared by Woulfe[13] back in 1771 and Dumas[14] had appropriately christened it after the Greek word πικρός, meaning bitter. However, the discovery of its properties as a stable disruptive explosive was new and its use as such was epochal. It was the first modern high-powered explosive. It made the coal-tar dye factory a potential munitions plant. No one was better able to understand and value the full implications of these facts than the Germans.* Certainly at that time no one was so well equipped to take advantage of them. Almost immediately the German High Command and the leaders of the German coal-tar chemical industry entered into an active cooperation which was to have a momentous outcome.

As early as 1904, the larger German coal-tar chemical manufacturers had gravitated into two "communities of interest," Badische-Bayer-Agfa and Hoechst-Kalle-Cassella. Within each group they pooled patents, distributed production to avoid duplication, allocated markets, and controlled prices. Shortly the two groups entered into a broader cartel which informally, but most effectively, banded the whole German industry into one working unit.

In the laboratories of Badische, which apparently specialized in this

---

* "A couple of weeks before the outbreak of hostilities the British dyemakers, Read, Holliday & Sons, shipped 50 tons of picric acid as a dye to Austria." (R. C. Jeffcott, to author, Sept. 23, 1942.)

work, a great number of organic nitro compounds were prepared and in all sorts of combinations turned over for testing by the ordnance officers of the General Staff. It was not long before a rumor was noised about that the Germans had selected trinitrotoluene—the TNT of the World War—as their disruptive explosive, and henceforth the makers of the coal-tar dyes and medicinals the world around found their German competitors waging a ruthless campaign to dominate the coal-tar chemical markets. It was no secret that the German Dye Cartel received preferential treatment from the German Government: rich subsidies for research, active cooperation from commercial attachés in foreign countries, favorable rates on the state-owned railways, and even the remission of certain taxes. Nor were the peculiar advantages, both technical and commercial, of trinitrotoluene as a high-powered explosive unappreciated outside of Germany.

Although the British certainly did not carry this knowledge "to its ultimate conclusion in unmitigated act," nevertheless, they were neither so stupid nor so careless as some of their chemical critics have intimated.[15] No doubt they failed to comprehend fully the position which the coal-tar chemicals had come to occupy. Even if they had done so, it would have been exceedingly difficult for them to have regained coal-tar independence. By this time the Germans had a long head start. To protect the British dyemakers would have required a very high tariff on German dyes and such a move would have been directly contrary to the cherished British philosophy of free trade. Moreover, such a tariff would have directly embarrassed their important and powerful textile industries which were already beginning to feel the pressure of German and American competition and which naturally wanted to buy the best dyes at the lowest price. After the coal-tar horse was stolen from England, it would have been difficult to lock the door.

British military authorities recognized the superiorities of trinitrotoluene, but in sticking to trinitrophenol they displayed considerable common sense. Great Britain was coking more coal than Germany, but was making only rough recoveries of the crudes. English plants had specialized in phenol and the cresols, developing a large, worldwide business in these materials and in the disinfectant specialties prepared from them.[16] Consequently, they were much better supplied with phenol than with toluene. They had, moreover, providently worked out a low-cost, high-yield, commercial operation for the familiar synthesis of phenol by sulfonating benzene. Their command of the phenol market was held through the recovery of this crude from gasworks tar by distillation, so that the synthetic process, while worked out on plant scale, was operated chiefly when world demand required

Chemical Industries

HORACE BOWKER

Industrial & Engineering Chemistry

W. H. NICHOLS

E. R. GRASSELLI

HENRY HOWARD

more phenol than the British coke and gas ovens furnished. It stood by, however, as a reserve in event of war needs for phenol for the manufacture of picric acid.

The research staff at the Woolwich Arsenal had experimented with numerous picric acid combinations and selected for lyddite the formula: picric acid 87 per cent, nitrobenzene 10 per cent, vaseline 3 per cent. At the same time our Navy was using as a service charge for armor-piercing shells dunnite, the so-called "Explosive D," a mixture of picric acid and ammonium picrate.[17]

Apparently neither the English nor ourselves appreciated that ammonium nitrate detonated with either picric acid or trinitrotoluene makes a comparatively economical, yet almost-as-potent disruptive. This fact was driven home by analysis of the charges of German "dud" shells which were found to be loaded with TNT and ammonium nitrate, and it emphasized the military importance of the nitrogen-fixation process. British, French, and Americans all failed signally to provide adequately for the fixed-nitrogen needs of a major, modern war; but even the carefully calculated estimates of the German High Command fell grossly short of what their nitrogen requirements actually became. Their cocksure plan for a swift campaign bogged down at the Marne and the recently perfected Ostwald process for converting ammonia to nitric acid failed on coke-oven and gas-house ammonia (due to impurities that poisoned the catalysts). Only the capture of 300,000 tons of Chilean nitrate of soda at Antwerp enabled the Germans to bridge the nitrogen gap, till the Haber synthetic-ammonia operation of the Badische plant at Oppau could be enlarged and a new plant at Merseburg built to supply sufficient pure ammonia.[18] The British cruisers kept the seapath to Chile open so that the Allies' improvident neglect of nitrogen, while it became critical, did not become desperate. In Germany the need for synthetic ammonia was imperative and no chemical operation within the Reich was so feverishly and so largely expanded during the war. Thus, to the coal-tar lesson was added the second great chemical precept of modern munitions: A self-contained synthetic ammonia industry, because of the purity of its product and its immunity from the threat of blockade, is the sole, safe reliance of a nation engaged in a large-scale, modern war.

In France, the favored military explosives in 1914 were nitrocellulose for propellants and picric acid for disruptives. The production of both was on a smaller scale than in England, and the early loss of the Alsace coal fields to the enemy made it quite impossible to munition their own troops. Accordingly, to the British demands upon us, were added those of the French.

In the United States we were producing some phenol in the coking of coal, none by synthesis; but we were recovering more than 10,000,000 gallons of benzene a year, sufficient for our needs for it as a fuel, solvent, and dry-cleaning agent.[19] Naturally, the first call from the Allies to us for high-explosive materials was for benzene. Following the same logic, the conversion of benzene to phenol by sulfonation was the first large-scale, aromatic organic synthesis we attempted. As this involves a rather simple technique, the phenol synthesis was a good introductory experience for both our chemists and our plant operators. Furthermore, the commercial incentives to produce phenol were tempting. During the early months of 1914 the German Dye Trust, possibly with foreknowledge of the coming war,* had been raiding the world's phenol market, challenging England's last coal-tar stronghold. The price of phenol in New York had dropped to 7¢ a pound, which at the time was said to be less than the cost of production.[20] By January 1915, the price was 50¢, a month later it jumped to $1.00, and by July had reached $1.50.[21] The cost of benzene had, of course, advanced at the same time, but not so rapidly.† The prospective profits stimulated, as we shall see, a number of hardy chemical adventurers to undertake this untried operation.

From the synthesis of phenol to its conversion into picric acid was a logical step, since picric acid was eagerly sought by English and French armies both, and afforded opportunity for an additional profit.‡ Phenol to picric acid was accomplished by sulfonation, followed by nitration of the disulfonic acid. Neither operation was particularly difficult, but each step required a large excess of exceedingly pure, high-strength acid, which at that time was not available in this country in the quantities required. On the heels of the British demands for benzene and phenol came a call for toluene and aniline. Thus the American coal-tar industry was launched on a great wave of munition demand. Thus, too, as this new venture advanced, it created a demand for more and more coal-tar crudes and intermediates and for new grades and undreamed-of quantities of many inorganic chemicals.

* "I do not believe the German Dye Trust had any foreknowledge of the coming war. My reason is that I spent a few days in the Leverkusen works of the Bayer Company in May 1914, and made a contract for the Merrimac Company to act as agent of the Bayer Company for the steam meters which they were using throughout their works at that time, which had impressed me most favorably. I made this contract directly with Dr. Carl Duisberg. It was not an important matter, but he gave considerable time to it, which he certainly would not have done, if he had been forewarned of the coming war. The first shipment of these steam meters arrived in New York about a week after the war started." (Henry Howard, to author, Sept. 21, 1942.)

† Benzene quotations, spot N. Y., were: July 1914, 20¢ lb.; Jan. 1915, 34¢; Feb. 1915, 35¢; July 1915, 75¢. See also Appendix II.

‡ Picric acid quotations, in kegs, f.o.b., were: July 1914, 40¢ lb.; Jan. 1915, $1.00; Feb. 1915, $1.25; July 1915, $1.50. See also Appendix II.

REFERENCES

1. Mitchell, *Business Cycles*, pp. 356-81.
2. Mills, *Behavior of Prices*, pp. 115-27.
3. W. M. Persons, *Rev. Econ. Statist. 9*, 20 (1927); C. Snyder, *J. Am. Statist. Assoc. 19*, 189 (1924); W. R. Burgess, *J. Am. Statist. Assoc. 18*, 727 (1923).
4. Mitchell, *op. cit.* Chart 21, p. 368.
5. Noble, *New York Stock Exchange and Crisis of 1914*, p. 3.
6. Haynes, *Chemical Pioneers*, p. 144.
7. J. R. Withrow, *J. Ind. Eng. Chem. 8*, 454 (1916).
8. Van Gelder and Schlatter, *History of Explosives Industry in America*, p. 797.
9. Chief of Ordnance (Army), *Ann. Rept. 1919*, 312; A. A. Claflin, *Chem. Mkts. 23*, 355 (1928).
10. Morgan and Pratt, *British Chemical Industry*, p. 257.
11. Miall, *History of British Chemical Industry*, p. 39.
12. *Ibid.* p. 384.
13. *Phil. Trans. 61*, 114.
14. *Ann. 39*, 350 (1841).
15. Claflin, *op. cit.* p. 356.
16. Gardner, *British Coal-Tar Industry*, p. 284.
17. Van Gelder and Schlatter, *op. cit.* p. 942.
18. Claflin, *op. cit.* p. 354.
19. D. W. Jayne, *J. Soc. Chem. Ind. 33*, 1178 (1914).
20. *Weekly Drug Mkts.* 7 (May 19, 1915).
21. *Ibid.* 16 (Jan. 5, 1916).

Chapter 3

TRENDING TOWARDS WAR

PRO-GERMAN SENTIMENT IN N. Y. CHEMICAL TRADE—BRITISH BLOCKADE DISRUPTS AMERICAN SHIPPING—GERMANY FAILS TO BARGAIN THEIR DYES AND DRUGS FOR OUR COTTON AND WOOL—RETALIATES WITH POTASH EMBARGO—UNRESTRICTED SUBMARINE WARFARE: "LUSITANIA" SUNK.

DURING THE EARLY stages of the war, sentiment in chemical circles, as throughout the country, was divided. However, in the drug and chemical trade, particularly at its headquarters in New York City, many of the leaders were definitely pro-German.[1] This was natural, since at that time a large portion of our business, not only in coal-tar dyes and medicinals, but also in fine chemicals, crude drugs, and essential oils, originated in Germany.

British heavy chemicals—particularly the alkalies, mineral acids, the alums, and other inorganic salts—still occupied a commanding position in world trade. It was in these same products, however, that American chemical manufacture had made greatest headway. Germany, on the other hand, had been assiduously cultivating newer, less-tilled fields—the coal-tar chemicals, the cyanides, prussiates, ammonium compounds, formaldehyde, chlorine, carbon tetrachloride—and had been intelligently and vigorously exploiting her natural monopoly of potassium salts both in the fertilizer and chemical sectors. London was still world headquarters for most of the nonferrous metals, for vegetable oils, crude drugs, and the spices and essential oils of Eastern origin; but Hamburg was a real rival and actually controlled the international market for many medicinal and aromatic raw materials from Central Europe, the Balkans, and Russia.

Since the eighties, therefore, our chemical and drug contacts with England had been weakening, while those with Germany had been becoming stronger and more intimate. By 1914 many of the most influential firms in the trade here were either the branch offices or the recognized sales agents of German chemical and drug companies. The heads and chief executives of these houses were almost without exception men of German birth or descent, whose innate allegiance was to the Fatherland.

Americans who long had had intimate business associations with German companies, remembered warmly the cordial hosts who had enter-

J. D. PENNOCK

HORACE G. CARRELL

EDWARD A. WILLIAMS

JOHN F. TIM

tained them at the opera and in jolly, informal beer gardens. They found it exceedingly hard to identify these friendly people with the Huns of the newspaper headlines. Furthermore, many of our leading chemists had been trained in the laboratories of Fischer, von Baeyer, Victor Meyer, Bunsen, von Liebig, Wöhler, von Hofmann, and a score of other famous German teachers. As students in the German universities, they had acquired, along with a wholesome relish for German beer and potato dumplings, a slightly idolatrous respect for German chemical accomplishments.

All our pro-German chemical people knew very well on which side their bread was buttered and on which shelf the jam-pot stood. The wish was father to their thought that the war would be quickly won and normal prewar relationships smoothly reestablished. Interference with this trade by the British blockade touched their pocketbook nerve and they reacted violently with loud protests. It was quite easy for them to follow the line of the German arguments: first, that American chemical manufacturers, for lack of the know-how, could not possibly achieve independence in coal-tar products during the war; and second, that when peace was restored, American textile, paper, leather, and pharmaceutical industries would be crippled by any tariff sufficiently high to protect our infant organic chemical enterprises from their experienced, efficient European competitors.[2]

It was dangerously easy to be pessimistic about the prospects of an American coal-tar chemical industry. The record of the past was clear. Not only had the German Dye Cartel resorted to every competitive trick—cut prices, commercial bribery, and full-line forcing—but had also cleverly used our own patent laws both to maintain its monopoly and to prevent anyone in this country from acquiring practical manufacturing experience in this field.

Unlike most countries, the United States has no "working clause" in its patent law. Once new products and processes developed by the extensive German research organizations were thoroughly covered by American patents, the German owners were under no compulsion to manufacture here or to license anyone else to do so. The Germans valued this system so highly that, when an effort was made to add a "working clause" to our patent laws, the German Government cleverly engineered a treaty with the United States. Germany agreed to suspend forthwith the working clause in her patent system, so far as American inventors were concerned, in return for an agreement by the United States that, should a working clause be added to our patent laws, it would not apply to German inventors.*

---

* For Henry Howard's account of German patent machinations, see Vol. III, Appendix LI.

All the Cartel's manufacturing was done in Germany. By putting as high a price as the traffic would bear on these synthetic chemicals, it reaped rich profits which enabled it promptly to amortize costs of research, plant investments, and the heavy expenses of forced sales campaigns. Thus, German chemical manufacturers were well able, after the American patents had expired, to reduce the price so low that it was not inviting to competition. If any American manufacturer had the temerity to make the product, the price was immediately cut below his production costs.

It was a good system and it worked so efficiently that any hope of an American coal-tar chemical industry seemed very dim. This defeatist attitude, essentially commercial and Teutonic, was gradually supplanted in our drug and chemical industries by a militant patriotic spirit of chemical independence that achieved the astonishing results of our war effort.

Throughout the nation at large, however, sentiment was almost from the first distinctly pro-Ally. Many leaders in business and finance, leaders also of public opinion in press, pulpit, and schoolroom, were Americans of stock descended from English pioneers who cherished English traditions of culture and political thought. We were bombarded with propaganda from both sides, but the Entente Allies had distinctly the best of the battle of words. Germany's ruthless, if realistic, violation of Belgian neutrality was vividly portrayed in atrocity stories which lost nothing in the telling. Our sensibilities had been shocked when the German Chancellor von Bethmann-Hollweg had cynically referred to the treaty guaranteeing that neutrality as "a scrap of paper," and the conception of the Germans as the reincarnation of the Huns seeking again to despoil and dominate all Europe became the background of most American thinking.*

Though as individuals our citizens failed rather conspicuously to heed the plea of President Wilson for neutrality "in thought as well as in action," no propaganda, however clever and compelling, could have ever involved us in the war. We were affirmatively pacifistic. Washington's admonition to avoid entangling ourselves in European affairs had become a well-grounded tenet in our national creed. The conflict generated plenty of heat in debate, but it would have ended here in words had not American lives and properties become involved in the struggle.

Britain's blockade of Germany raised the ancient issue of the freedom of the seas. For this principle, during the Napoleonic conflict, we had

---

* For a brilliant description of the progress of American thought at this time and a conscientious analysis of the course of President Wilson's official position, see Beard, *Rise of American Civilization*, pp. 611-35.

fought the War of 1812, and now this doctrine was enormously complicated by a new naval weapon, the submarine. With scant regard for the rights of neutrals, both belligerents proceeded to write their own amendments to the rules of war. Finding that the submarine made it dangerous for a ship to stand by and search a merchantman for contraband on the high seas, the British Admiralty adopted the policy of taking prizes to an English port. There, at leisure, cargo and mails were ransacked. On the other hand, the Germans, having learned how vulnerable a submarine is before an armed merchantman, ignored the old laws safeguarding the crews of these vessels. The U-boat commanders received orders to torpedo without warning any cargo ship in the war zone.

Chemicals furnished one *case célèbre* in the British interpretation of the new-style blockade. Early on a sparkling April morning, the American steamer, *Ogeechee*, from Bremen bound for New York, was overhauled by a British cruiser. Loaded chiefly with drugs and chemicals,[3] she was summarily ordered to proceed to Sharpness, where the British had established their examination depot for captured vessels. Among the more important items of the 450 shipments making up the cargo, were consignments of 325 cases potassium permanganate to Phillip Bauer Company; 11 casks potassium prussiate, A. B. Ansbacher & Company; 12 cases antimony lactate, B. T. Ancas & Company; 99 barrels Epsom salt, the Grasselli Chemical Company; 90 casks oxalic acid and 2,215 cases naphthalene, Roessler & Hasslacher Chemical Company; 20 casks potassium·permanganate, McKesson & Robbins; 225 casks tartaric acid, Merck & Company; 15 cases essential oils to Magnus, Mabee & Reynard; 99 bags of fennel and 41 barrels chamomile, Smith, Kline & French; and a shipment of laboratory glassware, filter paper, and scientific apparatus, Johns Hopkins University.

On May 3, 1915, the *Ogeechee* sailed for New York again, but without this cargo. The owners protested through the State Department and a month later the American-owned goods were released.[4] It was the general opinion of the trade that this would be the last consignment of chemicals to reach the country direct from Germany. By this time the British Orders in Council had declared practically all chemical and drug supplies to be contraband of war.

The first sudden crash of war paralyzed our foreign trade, but during the closing months of 1914, more or less normal shipments, both of exports and of imports, were resumed.* Indeed, the importation of some chemicals increased enormously. During November we brought in, chiefly from Germany, coal-tar dyes valued at $1,081,000 against $520,000 during the same month the year before. Alizarin and the

---

* See Appendixes III and IV for chemical imports and exports during the war.

alizarin dyes made a remarkable gain, $414,642 compared with $31,751 in November 1913. Exceedingly heavy shipments of creosote oils, sodium cyanide, quebracho, and camphor were also landed. On the other hand, shipments to us of glycerin, phenol, fusel oil, magnesite, and carbonate of potash all fell far below the average.[5]

Though many of these chemicals were of German origin, few were direct shipments. England was testing the efficiency of her blockade and trying out the sentiment in neutral countries. Several of these chemicals had not yet been declared contraband by her, and she was interfering as little as possible with shipments in neutral ships. Consequently, these chemicals came to us quite freely from Dutch and Italian ports.

German shippers generally consigned them to their American branches or to their regular American sales agents, to be sold for their account at the best price which could be obtained in a rapidly advancing market. In this way, Germany established a sizable gold credit here and used it to purchase needed supplies, chiefly cotton, nickel, rubber, and foodstuffs. The flood of these goods, which poured through the Scandinavian countries into Germany, would have to be dammed or the British blockade could not be an effective weapon.

In December 1914, the British determined to stop these leaks. A new contraband list, which included copper, aluminum, lead, and cotton, was issued. The Admiralty further announced that any shipment of contraband goods would in the future be seized, regardless of what flag the ship was flying or whether her destination was a belligerent or a neutral port. Our State Department vigorously protested this arbitrary interference with the trading rights of neutrals. The force of these protests was weakened, however, by the fact that England was only following a precedent of our own making. During the Civil War we had employed the same highhanded methods against contraband runners of our blockade of the Southern states.

Properly apprehensive of the effects of a really rigid blockade, Germany acted promptly. She made official representation to our Government that unless some arrangement were made with England whereby normal trade might be resumed in certain specific, noncontraband goods—cotton and nickel particularly—she would be forced to ban the export of chemicals, especially dyes, to the United States.[6] This was a heavyhanded effort to prod this country into more energetic, forceful action against the British blockade.

Official protests through diplomatic channels were not enough. Germany's affable and popular ambassador, Count von Bernstorff, called upon Secretary of State William Jennings Bryan and secured his sanction for a trade deal, whereby American cotton and wool would be

ALBERT R. BRUNKER

RUSSELL S. HUBBARD

JAMES E. PATTON

LEWIS R. ATWOOD

exchanged for German dyes and medicines. The proposed exchange of goods was to be financed through Hugo Schmitt, New York agent of the Deutsche Bank. The actual purchase of the textile fibers was arranged by Herman A. Metz, American agent of Farbwerke Hoechst, who was also congressman from New York and throughout this period the most active, aggressive, and successful supporter of German dye interests in America. The ambassador even came up to New York, where he sat in conference with Colonel Metz, a Mr. Rose, then foreign trade advisor to our State Department, and Mr. Forstmann * of Forstmann & Huffmann, important wool brokers. Forstmann, being a competent wool expert familiar with European requirements, was chosen to purchase the wool in this deal.[7] A Mr. Burr, later legal advisor of the Textile Alliance, was also present at this meeting.

The pinch of the coal-tar dye famine was beginning to hurt our textile industry, and already there was talk of mills closing down for lack of colors. Salvarsan, cinchophen, and other important medicinals were almost unobtainable and physicians were protesting officially through their medical associations. Secretary Bryan, avowedly a pacifist and free trader, resented almost personally the dislocation of our foreign trade and he had good reasons to make every possible effort to maintain the freedom of the seas. He was not wholly unsuccessful in relaxing the blockade. The British were adamant against permitting any goods useful to the war effort to reach Germany. They were not so strict, however, when it came to the shipment of German chemicals and dyes to this country. In the first place they did not feel that military necessity required it. Furthermore, they were anxious to have their blockade arouse no more resentment among Americans than was necessary.

After receiving official assurances that none of the chemicals so imported would be shipped out of this country, they permitted a number of American ships to bring limited cargoes of German chemical supplies from Rotterdam. The *Matanzas* arrived in New York on November 15, 1914, with 3,500 tons of dyes,[8] the current sales value of which at that time was estimated to have exceeded a million dollars. The success of this venture cheered the textile industry and when, within two weeks, the *American Sun* reached New York with a cargo of more than 4,000 tons of German dyes and chemicals, the confidence of the textile men was so restored, they began to believe that their

---

* "Forstmann told me that as a young man he was in an office of the German Government, whose business it was to study the tariffs of other countries and advise their manufacturers and exporters how to circumvent them, as filling the empty spaces of a piano-packing case with silk goods, etc., to get them in duty-free because of a loophole in some South American tariff law that based the duty on the case contents by the volume of the case." (R. C. Jeffcott, to author, Oct. 1, 1942.)

mills would continue to be supplied with colors throughout the duration of the war. The *Matanzas'* cargo consisted wholly of dyes; the *American Sun's* chiefly so.[9] There was great disappointment that so few drugs were included. The German agents were at pains to explain that this was because America's pressing need was for colors to keep the textile industry going. But it began to be whispered about the trade that Germany, herself, had good need for all the medicinal chemicals she could turn out.

Later, the steamer *Massapequa*, previously chartered by the Rockefeller Foundation to carry a cargo of food and clothing to the Belgians, returned from Rotterdam with a half-cargo of German drugs, chemicals, and dyes.[10] Her hold was not crammed with this precious freight for the very good reason that the supply of these German goods in the Dutch port was beginning to run low. Again the German agents in this country hastened to explain that they had recent advices from the German Government, indicating that large amounts of potash, medicines, heavy chemicals, as well as dyes, had been released for shipment to America. During December, Conrad H. Ruhl, the New York ship broker who had chartered the *American Sun*, concluded arrangements with the aid of our State Department to ship four more of these German chemical cargoes from Dutch ports, in American bottoms.

By the beginning of 1915, even these unsatisfactory arrangements for an uncertain and expensive supply of German chemicals were abruptly broken. The German Government nationalized all food supplies to facilitate their rationing system. England immediately declared all foodstuffs contraband of war, and it soon became plain that the Admiralty had issued orders to the fleet to tighten the blockade. British cruisers began picking up American and other neutral vessels, convoying them to Scotland where all goods of German origin were forthwith confiscated. The dribble of German chemical supplies to this country was abruptly and completely cut off.

Herman Metz, who had gone to Germany to arrange, if possible, for regular shipments of dyes and medicinals to this country, presented to President Wilson on his return, in June 1915, a statement from Dr. Adolph Haeuser, president of the German Chemical Manufacturers' Association, which clearly set forth the German position at that time: "We are gladly ready to send dyes to America, but we rest on the standpoint that we cannot accept this as a favor or gracious act on the part of England but that we can only send dyes when England recognizes the right of America to receive goods from us and you send us cotton in exchange for such dyestuffs."[11]

To emphasize this position and again to spur us to renewed and greater efforts to secure concessions from the British, Germany had, on January 29, 1915, placed an embargo on all potash salts. Overnight, potash prices in New York leaped forward and potash joined coal-tar dyes and medicinals as famine materials in this country. The import figures for February 1914 and 1915 graphically reveal the situation. In the February before the war, we had imported 102,729 long tons of potash fertilizer salts valued at $1,088,292. In the same month of the year after the war started, there were brought in 26,948 long tons valued at $929,362.*

Any prospect of relieving the potash crisis was gloomy. Even if our Government should obtain from the British free passage for this essential fertilizer material through the blockade, it was recognized that both English munition plants and farmlands were in as dire need of potash salts as ourselves. Under the circumstances, Germany would no doubt be as rigid in her embargo as was England in her blockade.

Nevertheless, Washington did not cease its efforts and there began a series of three-cornered negotiations with London and Berlin.† These were violently interrupted by Germany's sudden announcement that, beginning February 18, 1915, the waters surrounding the British Isles were a war zone in which any enemy merchant vessel would be sunk on sight by her submarines. At the same time Germany warned all neutral vessels that, as British captains were known to be sailing under false colors, any merchant ships that entered this war zone did so at their own peril.

This was, of course, Germany's logical interpretation of the rules of war for submarines. Obviously they could not seize and search a merchantman nor even convoy her as a prize to a German or neutral port. Two Standard Oil tankers were sunk and several American lives lost. Sentiment in this country was beginning to run high against Germany. The Allies had violated the freedom of the seas, interfering with American trade, confiscating American-owned goods, even opening American mail. All this aroused bitter resentment, but murder on the high seas was a very different matter. Excitement was screwed up to a high pitch when an advertisement appeared in the morning newspapers of May 1, 1915, signed by the German Embassy in Washington, warning American citizens against the dangers of the war zone and especially against the risks they ran traveling in English ships. That very day the *Lusitania* sailed from New York. Six days later she was sunk by two torpedoes without warning and 124 Americans were drowned.

President Wilson immediately demanded that the German Government disavow this act, make reparations, and take steps to prevent its

---

* The potash situation is discussed more fully in Chaps. 13-15.

† For an interesting inside view, see Hendrick, *Life & Letters of Walter H. Page*, I, pp. 367-97.

recurrence. He ended his note with a solemn warning that this Government would not "omit any word or any action necessary to the performance of its sacred duty for maintaining the rights of the United States and its citizens and for safeguarding their free exercise and employment."

The German Government temporized and attempted to bargain unrestricted submarine warfare against a relaxation of the Allied blockade. Although, after four months of diplomatic wrangling, Germany finally agreed to sink no more liners without warning and adhered to this policy for almost a year, the die had been cast. The trend was now definitely towards war. Preparedness became a popular catchword, and for the first time the establishment of a self-contained coal-tar industry in the United States became a matter of national concern.

REFERENCES

1. *Weekly Drug Mkts.* 7 (Oct. 7, 1914).
2. M. L. Hamlin, reviewing the articles of O. N. Witt [*Chem. Ztg. 38*, 1117 (1914)], and H. Grossmann [*Ibid.* 1169] in *J. Ind. Eng. Chem.* 7, 73 (1915).
3. *Weekly Drug Mkts.* 4 (Apr. 28, 1915), 5 (May 5, 1915).
4. *Ibid.* 20 (June 16, 1915).
5. *Ibid.* 9 (Jan. 20, 1915).
6. *Ibid.* 2 (Dec. 30, 1914).
7. *Ibid.* 15 (Feb. 6, 1918).
8. *Ibid.* 9 (Nov. 18, 1914).
9. *Ibid.* 6 (Dec. 2, 1914).
10. *Ibid.* 7 (Dec. 9, 1914).
11. *Ibid.* 10 (Jan. 12, 1916).

Chapter 4

THE PREPAREDNESS CAMPAIGN

PRESIDENTIAL CAMPAIGN OF 1916—GENESIS OF COUNCIL OF NATIONAL DEFENSE—GEN. WOOD'S PLATTSBURG PLAN—CHEMICAL FAMINE UPSETS AMERICAN INDUSTRY—NAVAL CONSULTING BOARD MAKES INDUSTRIAL SURVEY—NATIONAL RESEARCH COUNCIL ESTABLISHED—BOGERT HEADS ACTIVE CHEMICAL SECTION.

THAT THE SLOGAN "he kept us out of war" was the most effective vote-winning device of the presidential election of 1916, is a distressing revelation of the wishful thinking Americans were indulging at that critical time. Save as an example of how astutely the political leaders of both parties judged the temper of the people, the contest was undistinguished. Democrats and Republicans alike studiously avoided real issues.

United and confident, the Democrats gleefully acclaimed Wilson their candidate. The Republicans and Progressives had difficulty in reconciling their differences and were dubious of their ability to defeat the President at the polls. After anxious searching and a great deal of maneuvering for position, they drafted a compromise candidate, Charles Evans Hughes, from the Supreme Bench. Both Wilson and Hughes preached peace and strict neutrality, but neither frankly discussed war issues. The campaign has been likened to children quarreling in hushed voices in the cage of a tiger.[1]

The balloting was prophetic of future political trends. Hughes won impressive majorities in the financial and industrial East. A great number of Western Republicans and Socialists in all sections switched to support Wilson. In this campaign the Middle West block, which since the Civil War had held the balance in national elections, lost this pivotal position to the trans-Mississippi states. In fact, had the Republicans carried California—lost because of a tactless personal feud with the popular Hiram Johnson—they would have elected Hughes.

The election of 1916 sealed officially the isolationist sentiment of the American people. The great majority, though attached to the Allied cause, simply refused to believe that America had any stake in the contest. They closed their eyes to the threatening prospect of a Europe dominated by the German military caste and would assume no responsibility for the course of world affairs. As Louis Adamic has pointed out, from the Pilgrim Fathers at Plymouth Rock to the latest immigrant at Ellis Island, our progenitors have all been escapists from Europe.[8] From many diverse sources, therefore, we have inherited a profound abhorrence of European entanglements. Our rich resources and the breadth of the Atlantic Ocean created a sense of security that encouraged this escapism. Any person who advocated adequate defense measures was branded a warmonger. Preparedness was condemned as militarism.

Not all Americans were blind to the ominous situation. A few faced the unpleasant facts unflinchingly and refused to suppress all recollections of the bitter, costly lessons learned in both our Civil and Spanish-American Wars. Naturally enough, many leaders of this group were conscientious, farsighted Army or Naval officers whose warnings were easily misrepresented by the pacifists as the special pleading of professional militarism. As early as 1902, General William Crozier, Chief of Ordnance, had advocated a larger army, and in 1910, the prospect of a general European war became so plain that it prompted the General Staff to make a special, confidential report to the Military Affairs Committee of the House of Representatives. This report inspired a bill providing for a Council of National Defense, which was introduced into the House by Richmond Pearson Hobson, the Spanish War hero, who was then a Representative from Alabama and an active member of the Military Affairs Committee. Although reintroduced in both the Sixty-second and Sixty-third Congresses, 1912 and 1914, this measure never came to vote.

As originally proposed, the Council of National Defense was a strictly governmental body. Its membership consisted of the Secretaries of War and Navy; four technical officers, two from each major branch of the service; three senators and three representatives. Its functions were to serve quite as much as a clearinghouse for information between the responsible, interested chiefs of the executive and legislative branches of the Government and to furnish an opportunity for personal contact and departmental cooperation, as they were to plan and execute any definite measures for the defense of the nation. In Congress particularly, this conception of the Defense Council as an entirely governmental agency existed even after the formation of the War Industries Board in 1918.

The actual outbreak of hostilities in 1914 naturally brought many recruits to the advocates of adequate preparedness. Newspapers and magazines began discussing defense. National associations of industrialists and local chambers of commerce passed resolutions urging Congress to act. Prominent citizens—most conspicuous among them was Theodore Roosevelt—endorsed the movement. Though at first the tangible results were meager, nevertheless all this agitation was useful in stirring up the people. Some it frightened, awakening them to the gravity of the situation; others it roused to appreciate the big tasks ahead.

In 1915 General Leonard Wood, who had long been pleading for a larger army, successfully launched his "Plattsburg plan." Intensive training for volunteer Army officers appealed to the country. Here was something definite in purpose and practical in method, yet it fitted in perfectly with the cherished idea of the Minute Man who drops his plow to grasp the sword.

More definite progress was made in the Navy. Even the most rabid isolationist recognized that this first line of defense could not be improvised overnight. The President approved and Congress authorized a "second-to-none" naval-building program that was by far the most important defense measure actually enacted prior to our entry into the war. Out of it came as a by-product the earliest conception of the tremendously important part which industry plays in modern warfare, and a working organization that was eventually to evolve into the War Industries Board.

It took an amazing time for the idea of total war to penetrate. Even in Germany, where for forty years all war plans had included the mobilization of industry and transportation, the High Command grossly underestimated its ammunition requirements, notably the need for nitrogen, and it failed utterly to make provision for the civilian population. The German General Staff planned a quick victory, so that as early as the check at the Battle of the Marne, it was forced to improvise and substitute. The British and French had no inkling of a "nation in arms," and, even when we entered the war, they had failed to harness industrial production to military needs.

For two years we had sat on the sidelines with all the spectators' advantages, observing the methods of modern warfare. The demands of the Allies for all sorts of munitions had given us practical war-production experience. While it cannot be said that we learned all the lessons, we had come to recognize some of the problems.[3] At least a few of our military and industrial leaders sensed that victory over Germany would depend quite as much upon materials as on men; that shortages were bound to develop; that the industries of the country must be reorganized to supply military needs; that civilian goods would have to be cut to bare necessities.[4]

Chemicals played a part in this awakening educational process. Our shortage of coal-tar dyes and medicinals and our dependence upon Chile for nitrates were dramatic lessons of the compelling influence of war upon industry. For the first time chemicals became news. Strange words—benzene, phenol, Salvarsan, salicylates—flashed in the headlines. Newspapers played up the chemical famine and delighted to print all sorts of wild chemical tales of colors from berries and barks, revolutionary discoveries by drug clerks and veterinarians, astonishing new processes that would confound the enemy. Seeking scapegoats for the plight in which the nation found itself, the daily press charged our chemical industry with everything from stupidity to connivance, for permitting the Germans to monopolize the coal-tar chemical field. The wicked wastefulness of the beehive coke ovens furnished the text for many a slashing editorial.

The chemical famine not only caught the imagination of the man on the street, it touched his life so that he felt its reality. Colors and medicines, explosives and fertilizers were tangible things. Chemistry came out of the classroom and laboratory and began to have a real meaning to many Americans. All this well-publicized pother was effective propaganda, teaching the industrial implications of modern warfare. The direct relationship between chemical industry and the military machine was clearly explained in a popular article by Dr. Leo H. Baekeland,[5] who was one of the first to point out the national importance of chemical self-sufficiency. The coal-tar industry, he insisted, shows that "the importance of an industry should not be rated by its sales, but by the indispensable uses of the product it manufactures." In 1916 this was economic heresy. It was, however, thought-provoking.

At the same time, the all-pervading effects of modern war were being emphasized by deeds as well as words. The shortage of dyes actually closed American textile mills. Scarcity of chemical supplies and high prices touched many other industries vitally. In the hard school of experience the farmer learned firsthand the effects of war upon nitrates and potash. Finally, the leaders of our chemical industry discovered a plain fact which they themselves had failed to recognize: Chemicals had come to occupy a key position in the industrial life of the country in peace and war.

Both within the industry and among the general public this revelation had astonishing effects. It brought a new sense of responsibility to chemical men, not only the executive in the office, but the workman in the plant, the chemist in the laboratory, the teacher in the college. They all stood now in a prominent position of national importance. They developed an industry consciousness. At the annual meeting of the Cleveland Chamber of Commerce, this new chemical spirit was vigorously voiced by a chemical man who had just been elected its president.[6] In a prepared address, Ralph L. Fuller * reviewed in detail

* Fuller was at this time vice-pres. of Harshaw, Fuller & Goodwin. Shortly after we entered the war, he moved to New York and organized Ralph L. Fuller & Co., one of the most active of the chemical brokerage houses of the war period.

DAVID W. JAYNE

JOHN M. MOREHEAD

WALTER R. ADDICKS

A. A. SCHLESINGER

the repercussions of the chemical famine upon American industry and linked the prophecy of a great chemical expansion in this country to a strong plea for preparedness that would be industrial as well as military. This sudden awakening of the chemical industry came at a good time, for any egotistical spirit which it might have engendered was engulfed in a wave of patriotism. The experience was wholesome and vivifying. It created for the first time a feeling of solidarity among our chemical manufacturers. It inspired much of the stupendous, extra war effort.

The sudden appearance of chemicals upon our national industrial stage had a quite different effect upon the American people.[7] It fostered two misconceptions which persisted for two decades. First, so overwhelming was the publicity given coal-tar chemicals, that our average citizen came readily to believe we stole from Germany a brand-new chemical industry during World War I, under the protecting guns of the British Navy.[8] Second, this publicity fastened the myth of German chemical superiority upon the public at the very time it was being disproved by the accomplishments of our chemists and industrialists.* From the legislative and financial points of view these misconceptions have conditioned the development of the industry.

First official recognition of the fact that industrial mobilization would be necessary came from the Navy Department as early as the summer of 1915. A big naval appropriation bill was in Congress and there was every prospect that a much enlarged ship-building program would be voted. Much of their daily work had impressed naval officers with the intricacies of the supply problem and the importance of technical cooperation with the industries. An advisory Board of Inventions was appointed, the membership of which was a radical innovation. Headed by Thomas A. Edison, with Peter Cooper Hewitt and William L. Saunders as vice-chairmen, it was composed of two representatives each, from eleven leading technical and scientific associations of the country. The members representing the American Chemical Society were Dr. Willis R. Whitney † and Dr. Leo H. Baekeland, inventor of the plastic,

---

* Over 200,000 reprints of T. R. Leigh's article, "Germany's Stolen Chemistry," from *Pharm. Era 51*, 211 (1918), were distributed by the publisher, D. O. Haynes.

† In 1904, after several years' part-time teaching at the Mass. Inst. Tech. (S.B., 1890), Whitney left to take full charge of the General Electric Co. Research Labs. at Schenectady. Here he organized one of the first industrial research staffs, becoming vice-pres. in 1928. During the war he developed a practical detector for submarines, and in peace made important contributions to electric lighting, climaxed by the tungsten filament and the gas-filled bulb. Besides serving on the Naval Consulting Bd., he was an original member of the Nat. Res. Council and served as pres. of both the Am. Chem. Soc. and the Am. Electrochem. Soc. He was awarded the Perkin, Chandler, and Gibbs medals and hon. degrees from Union, Pittsburgh, Michigan, Syracuse, and Lehigh. [See also Holland, *Industrial Explorers*, pp. 13-32; *Chem. Met. Eng. 24*, 99 (1921); *Gen. Elec. Rev. 36*, 2 (1932).]

Bakelite, and of the photographic paper, Velox. From the American Electrochemical Society, the representatives were Professor Joseph W. Richards * of Lehigh and Lawrence Addicks.† At the first meeting held in Washington, October 6 and 7, the Board of Inventions changed its name to the Naval Consulting Board.[9]

Although its complexion showed that this board was brought together in an advisory-technical capacity, nevertheless, almost the first task it undertook was a comprehensive survey of the industrial plants of the country.[10] The plan was an ambitious one. Under the chairmanship of Howard E. Coffin,‡ an Industrial Preparedness Committee was named. A nationwide organization of state committees, hand-picked from the membership of the various engineering societies, collected the data. They listed not only the important industrial establishments with their executive personnel, but also described their facilities for war work and classified each according to its capacity and the type of goods it could supply to the Navy. At the same time this survey polled leading industrialists on their opinion as to the likelihood of our being drawn into the war, and collected confidential information about their war contracts with the Allies.

Unfortunately, however, this work was undertaken prematurely to obtain the most valuable information. It was not yet known exactly what facts and figures would be most useful, and a number of manufacturing concerns, stating bluntly that they did not want any government orders in war or peace, refused to give the desired information.[11] Despite these deficiencies and difficulties, the survey was carried through most energetically and was completed by September 1916. It laid the

---

* Richards, an outstanding metallurgist, had previously served on the U. S. Assay Comm. (1897), was a delegate to the Internat. Geol. Congress in Russia (1897), and was on the jury of awards of both the Export Exhibit at Philadelphia and the Panama-Pacific Exposition. Always a prodigious worker, he strained his health in service with the Naval Consulting Bd., especially when active Washington representative during the influenza epidemic. He was the author of numerous texts, his *Metallurgical Calculations* having been translated into German, French, Spanish, Italian, and Russian. He was also one of the first and most influential advocates of wider use of aluminum, and for years an energetic, valuable member of Am. Inst. Min. Met. Engrs. and Nat. Res. Council. [See also *Eng. Mag. 50,* 204 (1915); *Min. & Met.,* Dec. 1921; *Metal Ind. 19,* 457 (1921).]

† Addicks retired in 1914 as chief engr. and supt. of the Chrome, N. J., plant of the U. S. Metals Refining Co., to enter private consulting practice as a metallurgical engr. He had been educated at Pennsylvania and Mass. Inst. Tech. (B.S., 1899), and as a young man engaged in mining in New Mexico for ten years. In 1921 he published *Copper Refining,* a standard text.

‡ Vice-pres. and chief engr., Hudson Motor Car Co.; pres. of Soc. Automotive Engrs. (1910); later member of the Advisory Comm., Nat. Defense Council, and chairman, U. S. Aircraft Bd.

groundwork for future industrial inventories and again focused the attention of the business community upon the larger problems of the war. During this survey, Howard Coffin coined a telling phrase, to visualize the role of industry in war: "Twentieth century warfare demands that the blood of the soldier must be mingled with from three to five parts of sweat of men in the factories, mills, mines, and fields of the nation in arms." [12]

Akin to the Naval Consulting Board and expressing the academic background of Woodrow Wilson, the National Research Council was established at his request by the National Academy of Sciences.[13] This new body was formally authorized by Congress, July 1916,[14] but without any appropriation for working funds. Like the Naval Consulting Board, the Research Council was a parliament of representatives of various scientific societies. Its purposes, however, were much broader. The Council was to coordinate the scientific research work of the country in order to secure greater efficiency in solving the problems of both war and peace. The Engineering Foundation, backed by the four principal national engineering societies, came to the financial rescue with an offer of the use of its resources, including the services of its secretary, Dr. Cary T. Hutchinson. Naturally, this generous proposal was accepted and an organization meeting was held in New York, September 20, 1916.[15]

Dr. George Ellery Hale, the astronomer who had directed both the Yerkes and the Mount Wilson observatories, was chosen general chairman, and three important committees were appointed: On research and education, Dr. Hale, chairman; on the promotion of industrial research, J. J. Carty, chief engineer of the American Telephone & Telegraph Company, chairman; and on a national census of research, Dr. S. W. Stratton, director of the National Bureau of Standards, chairman.

Chemistry was represented in the original setup of the Research Council by Professor Marston T. Bogert, organizer of the chemical group, Professor T. W. Richards,* Dr. A. A. Noyes,† and Dr. Leo H. Baekeland.

---

* One of the great chemists and teachers of his day; Nobel laureate; winner of the Davy medal of the Roy. Soc. and Faraday medal of the Chem. Soc. Lond., also Gibbs, Franklin, and Lavoisier medals; hon. degrees from Haverford, Clarke, Harvard, Yale, Royal Bohemian U., Berlin, Cambridge, and Oxford. Richards did distinguished work in atomic weights, thermochemistry, and electrochemistry. He was pres. of the Am. Acad. Arts & Sci. and Am. Assoc. Advancement Sci. He died Apr. 2, 1928.

† Noyes, who became chairman of the Nat. Res. Council in 1918, had recently left the Mass. Inst. Tech. to become dir. of the Gates Chem. Lab., Calif. Inst. Tech. A great teacher, he was the author of several famous textbooks, notably *Qualitative Chemical Analysis of Inorganic Substances.* He was awarded the Gibbs, Richards, and Davy medals.

This Chemistry Division was one of the most energetic and effective sections of the National Research Council. Gas warfare created entirely new, strictly chemical problems and this committee did exhaustive research on methods of combating poison gas, as well as the development of new gases. Other projects that it carried on, chiefly by volunteers as very little money was available, were studies on noncorroding alloys, chemical treatment of balloon envelopes, standards for munitions, and the fixation of atmospheric nitrogen.

Two other semi-official bodies dealing with particular aspects of preparedness were established: the National Advisory Committee on Aeronautics, created March 1915, and the National Committee of Physicians for Medical Preparedness, established April 1916. These organizations all indicated a growing appreciation of the importance of adequate preparedness for defense and emphasized that defense itself had ceased to be merely a matter of strong military and naval establishments.

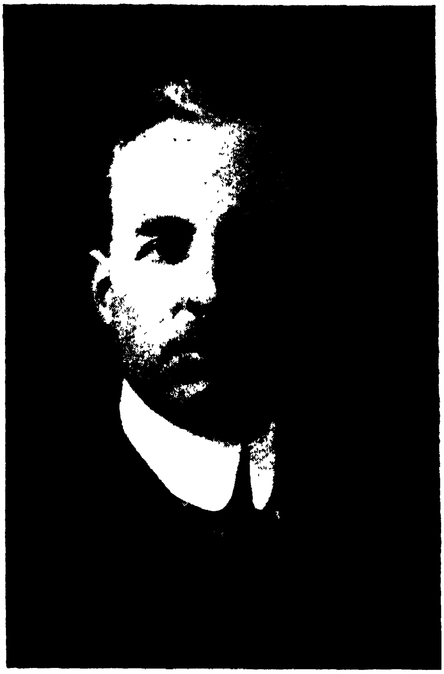
The man who was to crystallize these convictions appeared unexpectedly in Washington one sunny May morning in 1916. Dr. Hollis Godfrey, president of the Drexel Institute of Philadelphia, had worked out a plan to coordinate industrial activity with war effort in order to secure, as he himself put it,[16] "product and service at a minimum of cost and time." Naturally enough he took such a program to that great advocate of preparedness, General Leonard Wood.

"Three cheers!" exclaimed that vigorous enthusiast. "This is exactly what we need. There is nothing that is more necessary."

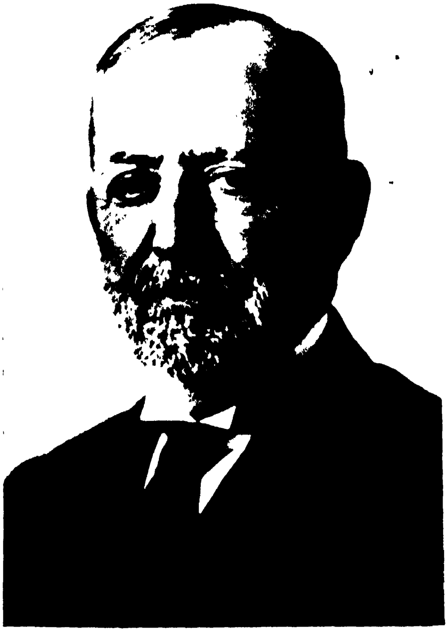
The seed of Dr. Godfrey's plan had been sown in 1906, when during a trip abroad he had met Sir Henry Campbell-Bannerman. At the time of this visit, his English host was hard at work with Winston Churchill, drawing the blueprints for a working council of imperial defense. He could talk of little else and so impressed was Dr. Godfrey that he became forthwith a solid convert who had eagerly followed every advance of the defense movement in the United States. When the time seemed opportune, Dr. Godfrey took his plan to General Wood. In collaboration with Secretary of Commerce Redfield and Dr. Henry E. Crampton, the distinguished biologist, they mapped out an American adaptation of the British defense council idea, and at General Wood's suggestion, Dr. Godfrey laid it before Secretary of War Garrison.

"This is the most amazing baby that has ever been put on the War Department's steps," said Secretary Garrison. "I am going to shut everything else off and talk to you the rest of the day."

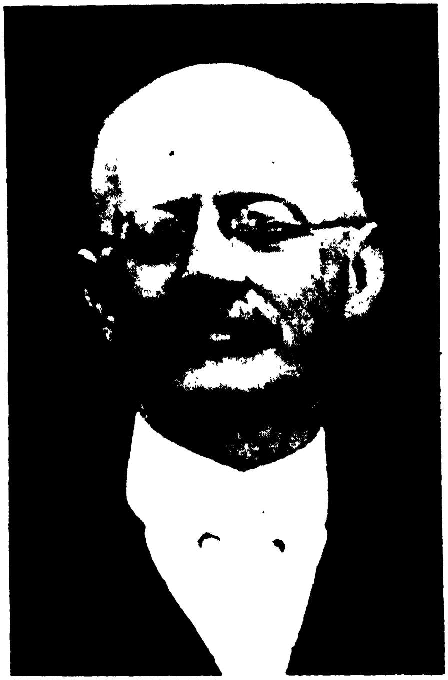
EUGENE M. MEYER, JR.



HUGH W. SANFORD



POPE YEATMAN



CHARLES CATLETT

REFERENCES

1. Slosson, *Great Crusade and After*, p. 23.
2. Adamic, *Two-Way Passage*, pp. 47-50.
3. Shadwell, Foreword to Clark's *Readings in Economics of War.*
4. Baruch, *American Industry in War.*
5. *World's Work 32*, 499 (1916).
6. *O.P.D. Reptr.* 15 (June 19, 1916); see Ann. Rept. of Cleveland Chamber of Com. for speech.
7. *J. Ind. Eng. Chem.* 7, 560 (1915); *J. Am. Pharm. Assoc. 6*, 98 (1914).
8. H. Wigglesworth, "The Chemical Industries," in Warshow's, *Representative Industries of U. S.*, Chap. 4.
9. *Met. Chem. Eng. 13*, 708 (1915).
10. Baruch, *op. cit.* p. 17.
11. Clarkson, *Industrial America in World War*, p. 13.
12. *Ibid.*
13. Nat. Acad. Sci., *Ann. Rept. 1916*, 22; *1917*, 46-70; *Proc. Am. Inst. Elec. Engrs. 37*, 909 (1918).
14. Clarkson, *op. cit.* p. 18; G. E. Hale, *J. Frank. Inst. 183*, 759 (1917).
15. *Met. Chem. Eng. 15*, 436 (1916).
16. Hearings Subcomm. No. 2 (Camps), Select Comm. Expend. War Dept. (House 66:1), Oct. 20, 1919, p. 180.

Chapter 5

GEARING INDUSTRY TO WAR

WAR INDUSTRIES BOARD UNDER BARUCH EMERGES FROM A WELTER OF DEFENSE PLANS AND ORGANIZATIONS—ADVISORY COMMITTEES FOR HEAVY AND FINE CHEMICALS FORMED—CHEMICAL ALLIANCE INCORPORATED BY MANUFACTURING CHEMISTS' ASSOCIATION TO HANDLE INDUSTRY'S WAR WORK.

AFTER THAT HISTORIC CONFERENCE, Dr. Hollis Godfrey's plan was drafted into legislative form by a notable group of preparedness advocates. The characteristic idea of the Advisory Commission was original with Dr. Godfrey and Dr. Crampton. Howard Coffin, out of his experience with the Naval Consulting Board, made practical administrative suggestions. To Senator Elihu Root, former Secretary of War, is credited the idea of a council of cabinet members. Some men very close to the President—Nicholas Murray Butler, Benjamin Strong of the Federal Reserve Bank, William G. McAdoo, and Colonel House—were consulted and Wilson's hearty approval won for the proposed measure.[1]

Having refused during the last three sessions to bring the Hobson bill to vote, Congress now extravagantly made double provision for a council of defense. The National Defense Act authorized the President to appoint a Board of Industrial Mobilization. The Army Appropriation Act of 1916 provided for the appointment by the President of a Council of National Defense. This was duplicated authorization. At the time no one noticed this, and it was the provisions of the Appropriation Act that were actually used to create the Council.*

This council was composed of six Cabinet members, the Secretaries of War, the Navy, the Interior, Agriculture, Commerce, and Labor. For appointment by the President they nominated an Advisory Commission of seven men, each well qualified in some special field to make his services of peculiar value to national defense.

Both Council and Advisory Commission were formally organized October 11, 1916. The Secretary of War was nominated chairman of the Council, Walter S. Gifford † was appointed director, and Gros-

---

* For text of law, see Appendix VI.

† Gifford, later pres. of American Telegraph & Telephone Co., was at this time that company's chief statistician. He had previously been director of the Naval Consulting Bd. and later served as U. S. representative on the Inter-Allied Munitions Bd. in Paris.

venor B. Clarkson was made secretary of both Council and Commission. Daniel Willard of the Baltimore & Ohio Railroad, the expert in transportation, was named chairman of the Advisory Commission, the other members being Dr. Hollis Godfrey, engineering and education; Howard Coffin, manufacturing and munitions; Dr. Franklin H. Martin, secretary of the American College of Surgeons, medicine and surgery; Bernard Baruch, raw materials; Julius Rosenwald of Sears, Roebuck & Company, supplies; and Samuel Gompers, president of the American Federation of Labor, labor relations.

When these seven distinguished authorities first gathered in a hotel room in Washington, December 7, 1916, they had little idea what was expected of them and certainly no notion that eventually they were to assume czar-like control over the war activities of all American industries. They were, however, men of broad experience, executives accustomed to authority and in the habit of making prompt decisions. They wasted no time asking for instructions, but came immediately to grips with their respective tasks. Belying its official title, the Advisory Commission almost from the first became the effective implement of the Council of National Defense.[2]

In the nature of things—the problems to be solved and the personalities involved being what they were—the growth of the Raw Materials Division into the War Industries Board under Bernard Baruch was a natural evolution.* It was accomplished in a faltering, almost haphazard manner, but it must not be forgotten that the position of the Advisory Commission was anomalous. Although charged with grave responsibilities, it existed only in an advisory capacity and had no specific powers either of execution or enforcement.

In organizing the Raw Materials Division, Bernard Baruch † adopted two policies which eventually became exceedingly important in the industrial mobilization as worked out by the War Industries Board. He drew heavily upon the advice of experts who had no direct connection with the companies in the various industries involved, and he invited the industries themselves to name committees and subcommittees to work with his division.

Outstanding among his technical advisors was Leland L. Summers, consulting chemical engineer of New York. He had been well trained

---

* Two firsthand authorities trace the various steps in this evolution: Baruch's *American Industry in War* is a factual account of the development, while Clarkson, in *Industrial America in World War*, throws much light upon the men and problems involved in establishing wartime control over industry. See also, J. L. Tyson, *Fortune* S16 (Sept. 1940) and testimony of Lt. Col. R. H. Hawkins before Hearings Subcomm. No. 5 (Ordnance), Select Comm. Expend. War Dept. (House 66:1-3), Sept. 7, 1919.

† Baruch, a New York financier, had had broad experience in the development of mining properties, especially copper and sulfur.

for the task. During the previous two years he had served as technical consultant to J. P. Morgan & Company, who had charge of the British war purchases in this country. He was shrewd and farsighted, tireless and determined, and quite without any sense either of fear or of favor.[3] Clarkson has called him "the War Industries Board's alchemist of the wizardry of war."[4] The black magic that he practiced was a very modern, practical brand. He was well versed in the commercial aspects of coal-tar synthetics, air nitrogen, and explosives. Chemical people in contact with Summers came either to like or dislike him cordially, but all admitted his ability and nobody questioned his sincerity. He played a dominant part in many phases of our wartime chemical developments. But most of his work was done offstage, behind the scenes.

Baruch first learned of Summers through his Wall Street connections and invited him down to his South Carolina estate where, it is said, Summers spent the week end explaining the intricacies of chemical raw materials, supply and demand, product and by-product, as they had developed in the British war experience. Baruch was fascinated and appalled at the task before him and, turning to the chemical engineer, he invited him to join the Advisory Commission. Then, knowing that Summers was not a rich man, and that the men in his division served without pay, Baruch offered out of his own pocket to pay Summers the same salary he had been receiving as Morgan consultant.

"How much do you get, Mr. Baruch?" asked Summers.

"Nothing—I pay my own expenses."

"I'll come with you on the same terms," decided Summers.[5]

While Summers was conspicuous for his talents and was in closest contact with our chemical war effort, he was but one of several experts with war experience gained with the Allies whom Baruch drafted as consultants. By putting such trained, disinterested men in key positions among the various commodity sections, Baruch strongly fortified his mobilization plans. Later, when the problems of purchasing and priorities became paramount, these same men became invaluable coupling links between government and industry. They were above the suspicion of favoritism that was all too easily leveled against the dollar-a-year man with his big corporation connections.

Baruch's second great contribution was the idea of industrial committees. He reasoned rightly that if the industries named their own representatives, their own self-interest would prompt them to nominate able, fair-minded, courageous executives whom they could all trust. By these simple expedients he surrounded himself with energetic, patriotic, younger men with firsthand knowledge and practical experience, avoiding the dangers of greedy nepotism and the disadvantages of placing in executive posts men imbued with impractical theories or bureaucratic

HENRY C. DuBOIS

F. AUSTIN LIDBURY

W. ACHESON SMITH

FRANK J. TONE

spirit. Only rarely was his confidence in the industries and their self-appointed delegates misplaced. His man-finding methods became the model for other government agencies. All department heads did not have his skill in giving implicit instructions, his generosity in delegating authority, his swiftness to praise competent associates and to remove those who fumbled their tasks.

Early in the spring of 1917, while the Advisory Commission was making an industrial survey of the country, these industry committees began to take shape. One of the first organized was a special advisory committee to assist Baruch in raw materials and Rosenwald in manufactured goods.[6] On it served a number of chemical men: H. S. Rubens, United States Industrial Alcohol Company; William Hamlin Childs, Barrett Company; and Henry Whiton, Union Sulphur Company.[7] Shortly afterwards, a special chemical industry body, the Chemical Committee, was appointed, with Dr. William H. Nichols of the General Chemical Company as chairman and Major Joseph T. Crabbs as his executive assistant. Ex-officio members were Van H. Manning of the Bureau of Mines, C. A. Richards of the Department of Commerce, and Prof. Marston T. Bogert of the National Research Council. The members of this original chemical war committee were Eugene R. Grasselli, Grasselli Chemical Company; J. D. Pennock, Solvay Process Company; William H. Childs of Barrett; John J. Riker, E. D. & J. J. Riker Company; Horace Bowker, American Agricultural Chemical Company; Charles H. MacDowell, Armour Fertilizer Works; Charles G. Wilson, Virginia-Carolina Chemical Company; Edward Mallinckrodt, Jr., of Mallinckrodt Chemical Works; and A. D. Ledoux, the Pyrites Company, Ltd. This hand-picked group of leaders in various branches of the industry served also as chairmen of various subcommittees.*

This Chemical Committee of the Council of National Defense did excellent preliminary work. It met every other week, and during the early summer of 1917, at the suggestion of General Crozier, Dr. Nichols prepared a master plan for explosives production. This received scant attention and went into the wastebasket. Elon Hooker also prepared a plan for general industrial mobilization, but this was outside the Committee's jurisdiction and also got nowhere. Much practical work was done in lining up necessary supplies to cover requirements in event of war. Doctor Nichols, Baruch, and Summers did not agree on pricing policies. The Doctor favored a fairly high price to encourage production. Baruch and Summers did not think it good business or good politics for industry to make large profits during wartime.[8]

* For the roster of these committees, see Appendix VII.

While the chemical industry subcommittees were being set up, 250 manufacturers of fine chemicals and pharmaceutical products conferred in Washington with the Council of National Defense and elected a committee to cooperate in the survey of their industry. The chairman elected was Willard Ohliger of F. Stearns & Company; the secretary was Frank G. Ryan of Parke, Davis & Company. The committee members were Charles J. Lynn of Lilly; Theodore Weicker of Squibb; Milton Campbell of Mulford; Robert C. Stofer of Norwich Pharmacal; C. Mahlon Kline of Smith, Kline & French; Adolph G. Rosengarten of Powers-Weightman-Rosengarten; Herbert H. Dow of Dow Chemical; B. T. Bush of Antoine Chiris; A. J. Marcuse of West Disinfecting; and Saunders Norvell of McKesson & Robbins.[9]

Thus, under the Advisory Commission of the National Defense Council, both major branches of the chemical industry—heavy and fine chemicals—were first organized for their war effort. By this time, the cumbersome machinery of the Advisory Commission was beginning to creak and groan distressingly. Already the Raw Materials Division under Baruch had come to occupy a key position in the industrial mobilization of the country. Baruch was a shrewd and capable administrator, and the Commission, being without powers of enforcement, quickly discovered that the simplest, surest way to control the war effort was through priorities governing the supply of essential raw materials handled by Baruch's division.

Baruch had already organized his commodities sections with a personnel of disinterested experts and Army and Navy officers, supported in each field by advisory committees similar to the two already functioning in both branches of the chemical industry. His colleagues on the Advisory Commission depended chiefly on their industrial advisory committees, with the result that members of firms receiving big government orders occupied important advisory, even sometimes administrative, positions. After the war, a rabidly partisan, Republican Congressional committee, digging into war expenditures, could uncover no evidence of serious abuse of this influence. Nevertheless, at the time, the possibility of such favoritism roused considerable criticism. Congress, therefore, tacked onto the Food and Fuel Control Act of August 1917, a rider prohibiting any member of the Council of National Defense or its subordinate bodies from arranging contracts with any company in which he had a personal or financial interest.

This law forced a thoroughgoing reorganization of most subcommittees of the National Defense Council. The existing cooperating committees, representing all the principal industries of the country, were curtly dismissed and replaced gradually by the Baruch system of commodity sections. The Chamber of Commerce of the United States thereupon organized the abandoned committees as "War Service Committees of Industry," and called the chairmen of these groups to Washington on December 12 to perfect a plan for better cooperation between industry and Government.[10] Although previously the Advisory Commission had snubbed this patriotic move on the part of organized business, it now found these trade committees, popularly known as the "alcohol-to-zinc committees," a real help in building an effective war machine.

This reorganization increased efficiency and smoothed the way for the ultimate division of the Advisory Commission into the various war agencies, the War Industries Board, the Railroad, Fuel, and Food Administrations, the Shipping and the War Trade Boards. At this critical early period of the war effort, however, it threw the gears out of mesh. Fresh contacts had to be established. New men had to be educated to strange tasks. The supply of munitions stalled so badly, it became evident to everyone in Washington that it was necessary, first, to centralize Army and Navy purchases, and second, to divert most of the nation's industrial output straight to war purposes. Unless these things were done, proper allocation of needed materials and supplies, as well as correct timing, would be impossible. Utterly regardless of any needs save their own requirements, Army and Navy procurement officers were placing many orders far larger than their immediate wants. Naturally they ran up prices and prevented the flow of munitions and the raw materials of munitions to the most needed purposes. The country's transportation system was snarled badly and to bottlenecks in materials supply were added jams of shipping facilities. Shortages and bad distribution of chemicals appeared early in the fall of 1917. Notably, a shortage of sulfuric acid began to cause grave concern.

The first step toward a centralized, authoritative purchasing agency was taken only five days after war was declared. The Munitions Standards Board, which had been created by the National Defense Council on February 28, 1917, to cooperate with Army and Navy in establishing munitions standards, was reorganized a month later into the General Munitions Board. Frank A. Scott, vice-president of the Warner-Swasey Company of Cleveland, manufacturers of precision instruments, continued as its head.[11] This board had no authority to enforce its decisions, and Army and Navy officers, refusing point blank to take orders from civilians, continued their mad, competitive buying. Scott labored like a Hercules in the mess of these Augean stables, and out of his efforts to simplify the organization came, on July 28, 1917, the War Industries Board of the Council of National Defense. Here all the "alcohol-to-zinc" committees were gathered under a single head, but it still lacked authority to make good its decisions. Baruch and all his Raw Materials Division were absorbed into this organization.

The shortage of sulfuric acid which developed in the fall of 1917 shows how badly the wires crossed. Leland Summers, who was in charge of all chemicals in the Raw Materials Division, drafted March F. Chase, a specialist in the contact process.[12] Chase, a competent chemical engineer, had formerly been with the New Jersey Zinc Company and later became vice-president of the Commercial Acid Company, St. Louis. The same week, Food Administrator Herbert Hoover announced the formation of a Chemical Division of the Food Administration to be directed by Charles W. Merrill, a well-known metallurgical engineer of San Francisco.[13] The idea seems to have been that Chase would have charge of sulfuric acid as a munition and Merrill, of sulfuric acid as a fertilizer raw material. This unwise division of authority became positively ridiculous when a month later Charles H. MacDowell, president of the Armour Fertilizer Works, came to Washington to take control of nitrates and general chemicals for the War Industries Board. With Summers, MacDowell, and Chase on hand, the Chemicals and Explosives Section of the Raw Materials Division began to be whipped into some semblance of reasonable organization.* In December, Professor Bogert became technical advisor to this section. Shortly afterward, there were associated with him Dr. Herbert R. Moody † and Dr. Samuel A. Tucker.‡ Nitrates, involving critical supply problems connected with acids, ammunition, and fertilizers, were kept a separate entity. MacDowell was put in charge of nitrate supplies and a distinct Nitrate Committee for purchasing was organized with H. Ray Paige as chairman and manager.

Throughout the winter of 1917-18, the War Industries Board continued to operate as a subordinate body of the purely advisory Council of National Defense. It managed, however, to accomplish much.[14] It set up the priorities system to govern both supply and distribution of many raw materials. It fixed prices and established control over imports. Without any government subsidies and upon the basis of voluntary cooperation with private industry, it launched huge projects to increase production of many chemicals. During this period Baruch's

---

* For C. H. MacDowell's own account of this work, see Appendix XI.

† At this time Moody was prof. chem. at City College, N. Y. He was trained at the Mass. Inst. Tech. (S.B., 1892) and Columbia (A.M., 1900; Ph.D., 1901), after which he taught in schools and at Hobart. Besides being chief chemical technician of the War Ind. Bd., he was long a member of the Nat. Res. Council and was asst. admin. of the N.R.A.

‡ Tucker was also consultant to the Ordnance Dept. and a Major in the Chem. Warfare Serv. Later, he became chief chem. to the Chemical Foundation. He was prof. electrochem. at Columbia and curator of the Chandler Chemical Museum.

ROBERT M. TORRENCE

A. G. ROSENGARTEN

C. K. LEITH

EDWIN J. HALEY

approach to these problems was made clear and the methods of the War Industries Board in solving them were perfected. Both philosophy and action were fundamentally business-like.

Baruch believed in free, competitive enterprise. He respected the ability of industrial leaders and trusted them. He was conscious of the grave dangers of inflation which he sought to check at the base by controlling the prices of fundamental raw materials. In line with his thinking, the War Industries Board disturbed established business practice no more than absolutely necessary. Instead of attempting to lord it over industry in an arbitrary, bureaucratic fashion, the Board worked through existing trade and industrial organizations and with the individual firms. It shared responsibilities and got results because it expected the best patriotic cooperation. It negotiated shrewdly to save the Government money, but when it came to control over prices, since it had no authority "to order and then crack down," it explained the situation and reasoned for voluntary action. When it met unpatriotic selfishness, as it did rarely, it did not hesitate to bring recalcitrants into line by cutting off their raw materials through priorities or through the cooperation of the Fuel Administration and the Shipping Board, evoking what was a virtual industrial excommunication.

During this period important moves were made in the chemical field. In November, the pressing necessity for acetone led to a comprehensive allocation of the output of the wood-distillation plants. In like manner, when the platinum situation became critical, refinery stocks and all imports were commandeered. During December, an inter-Allied nitrate buying pool, the Nitrate Executive, was organized in London and the machinery set up in the United States both for purchasing and distributing this vital material. Vigorous measures were taken to increase the output of chlorine. Toluene was commandeered for war needs. The prices of sulfur and sulfur-bearing ores were fixed by agreement and the distribution of these essential materials taken in hand.

Despite these and other tangible, important accomplishments, a unified command on the economic front was increasingly necessary. What the commodity sections had accomplished, indicated that Baruch was the man for this important post. Accordingly, President Wilson, on March 4, 1918, wrote to Baruch, inviting him to become chairman of the War Industries Board. This letter * outlined in detail the duties of the new Board and delegated specifically to its chairman all wartime powers which Congress had invested in the President: to make government purchases, to control prices, to regulate production, mobilizing and enlarging, if necessary, the country's output, and to direct the dis-

---

* For full text, see Appendix IX.

tribution of products.* In this informal way—no act of Congress ever authorized or sanctioned the War Industries Board—the President bestowed upon Baruch and his associates powers only paralleled by those administered by the Minister of Munitions under the British Defense of the Realm Act.[15] In this way, although still without any legal authority to compel compliance with its rulings, the War Industries Board became the sole, supreme arbiter of American industry at war.

Somewhat previous to the creation of the War Industries Board, an organization was formed—the Chemical Alliance—which was destined to become the war board of the chemical industry. Back in July 1917, at the behest of the War Trade Board which had control of imports and exports, the Department of Commerce called together the makers and consumers of sulfuric acid. The matter under consideration was the imports of foreign pyrites, a problem delicately poised between the rapidly growing need for sulfuric acid and the increasing shortage of available shipping. At this meeting, sulfuric acid representatives were all members of the Chemical Committee, advisory to the War Industries Board, and of the Manufacturing Chemists' Association.[16] After conferring with the War Trade Board and consumers of sulfuric acid, these acid makers held an organization meeting in the Department of Interior Building at Washington, on August 1, 1917, and elected the following officers and directors: William H. Nichols, General Chemical Company, president; Horace Bowker, American Agricultural Chemical Company, vice-president; J. D. Cameron Bradley of Boston, secretary-treasurer. The directors were: E. R. Grasselli, Grasselli Chemical Company; William H. Childs, Barrett Company; Charles H. MacDowell, Armour Fertilizer Works; Charles G. Wilson, Virginia-Carolina Chemical Company; Henry Howard, Merrimac Chemical Company; John D. Pennock, Solvay Process Company; Edward Mallinckrodt, Jr., Mallinckrodt Chemical Works; John J. Riker, E. D. & J. J. Riker; A. D. Ledoux, Pyrites Company, Ltd. Messrs. Bowker, Grasselli, Howard, Nichols, and Pennock were named an executive committee.

As an aftermath of the sweeping reorganization of all the war agencies in Washington, in July 1917, Baruch requested the immediate formation of a representative chemical industry group to take over the

---

* "The War Industries Board did not actually make purchases or close contracts. The commodity sections advised the procurement agencies of the Army and Navy. The policy was to aid procurement in every way possible; to check prices and terms; to fix prices by appearing before the Price-Fixing Committee; to approve commandeering orders and prices to be paid under them; to have all matters concerning procurement, other than specifications, funnel through the commodity sections. At first, the Army in particular, avoided consulting the sections, but after sitting in on the discussions, they cooperated willingly—especially with the Chemicals Division." (C. H. MacDowell, to author, Nov. 23, 1942.)

Chemical Industries

EDWARD MALLINCKRODT, JR.

Chemical & Metallurgical Engineering

GEORGE P. ADAMSON

WILBUR N. WILKINSON

PORTER FLEMING

work of the old advisory Chemical Committee, its subcommittees, and this special Sulfur Materials Committee. As chairman of the executive committee of the Manufacturing Chemists' Association, Henry Howard investigated the Textile Alliance, a similar organization recently set up by the textile industry. Using this as a model, Arthur H. Weed, the Association's secretary, incorporated the Chemical Alliance under the club law of Connecticut. Howard presented this corporation, complete with bylaws and dummy directors, to the combined chemical group at a special gathering on December 4, 1917.[17] At this meeting, held in New York, William H. Nichols resigned as president and the vice-president, Horace Bowker, was named in his place; Henry Howard became vice-president.*

The incorporation of what was in effect the old Chemical Committee was a wise move. It gave that body standing and stability, and provided a convenient, equitable means for raising the necessary money to carry on the common war effort of the entire industry. The whole plan and program had been submitted in advance by the Manufacturing Chemists' Association to Baruch, Summers, and MacDowell, and Baruch wrote the new president a letter of cordial endorsement,[18] ending, "I trust that you will secure a broad and comprehensive membership to the end that the chemical industry may act as a unit in carrying on the great work which is ahead of us."

The members, who were shareholders, immediately grouped themselves into sections. Representing similar or allied interests, each section had full jurisdiction over its particular branch of the industry and each had direct relations with the Government. The board of directors set up the following sections: Acids, By-Products of Coal and Gas, Foreign Pyrites, Electrochemicals, Fertilizers, Miscellaneous Chemicals (chiefly fine and pharmaceutical), Alkalies, Domestic Pyrites and Sulfur, Dyestuffs and Intermediates, Tanning Extracts, Disinfectants, Insecticides. These sections, which paralleled closely the sections of the War Industries Board, worked through small active committees elected by the members, and the committee chairmen became, by virtue of their office, members of the board of directors.

This thoroughly representative body, with which every chemical manufacturing firm of any standing associated itself, thus furnished a simple, competent means of directing and administering chemical war activities. From time to time there were necessary changes in the personnel, but throughout the war, and long thereafter, as we shall see, the Chemical Alliance functioned smoothly and effectively. It brought together into close, personal contact the leaders of all branches of

---

* Appendix XII lists the complete membership of the Alliance.

American chemical industry. It made possible a cooperative effort unbelievable in so highly competitive and individualistic a field. The results of these contacts and this common effort were to be far-reaching.

REFERENCES

1. Clarkson, *Industrial America in World War,* p. 15.
2. W. S. Gifford, *Iron Age 100,* 419 (1917).
3. Baruch, *American Industry in War,* pp. 162, 165, 184.
4. Clarkson, *op. cit.* p. 90.
5. *Ibid.* p. 91.
6. *O.P.D. Reptr.* 16 (May 21, 1917).
7. *Ibid.* 18 (May 14, 1917).
8. C. H. MacDowell, to author, Nov. 23, 1942.
9. *Drug Chem. Mkts.* 6 (June 6, 1917).
10. *O.P.D. Reptr.* 18 (Oct. 22, 1917); 76B (Dec. 10, 1917); 19 (Dec. 17, 1917). See also, Baruch, *op. cit.* p. 22; Clarkson, *op. cit.* p. 302.
11. Baruch, *op. cit.* p. 19.
12. *J. Ind. Eng. Chem. 9,* 1149 (1917).
13. *Drug Chem. Mkts.* 15 (Oct. 24, 1917).
14. *O.P.D. Reptr.* 61 (Dec. 16, 1918).
15. *Ibid.* 25 (Apr. 8, 1918).
16. *Chemical Alliance, Inc.,* p. 13.
17. H. Howard, to author, Oct. 20, 1942.
18. *Chemical Alliance, Inc.,* p. 15.

PART TWO

CRITICAL RAW MATERIALS

Chapter 6

NITRATES FROM CHILE

UNIVERSAL DEPENDENCE ON CHILEAN NITRATE FOR FERTILIZER AND EXPLOSIVES—FOREIGN CONTROL OF DEPOSITS—WAR DEMANDS AND SHIPPING SHORTAGE BOOM MARKETS—VON SPEE BLOCKADES NITRATE FLEET—WAR INDUSTRIES BOARD COMMANDEERS NITRATE TO MEET CRISIS.

ESSENTIAL INGREDIENT of both fertilizers and explosives, nitrogen is doubly a "must munition," and we entered the war dangerously dependent upon a foreign source in the hands of a powerful, natural monopoly. To the very signing of the Armistice the nitrogen problem had not been solved. Throughout the war, American farmers called upon to help feed Europe were chronically short of this vital plant food, and at critical junctures serious shortages of ammunition, due to lack of nitrogen, created hazardous positions at the battle front. The need for nitrogen sat like Banquo's ghost at every Allied council table. It forced many an anxious decision.

With victory at stake and starvation threatening, the nitrogen situation was continually packed with drama. It became involved in world politics and furnished the clue to one of the boldest, most brilliant diplomatic coups carried off by our Government during the war. The interlocked needs for ammonium sulfate as a source of nitrogen and for coal-tar crudes and intermediates to make explosives, dyes, and medicines, were met by a stupendous effort which within three short years almost revolutionized the American steel industry. To fill the pressing need for fixed nitrogen, the Government undertook its most extensive, most expensive war-plant-building program. Long after the war, the nitrate plants at Muscle Shoals were to grow into the Tennessee Valley Authority—one of the greatest of the New Deal's experiments—the largest government-owned enterprise competing with private industry. It had grave effects upon the development of our important synthetic ammonia and fertilizer industries.

From more prosaic technical and economic points of view, the World War I nitrogen situation illustrates clearly the competition between the three basic types of chemical products: natural, by-product, and synthetic. Considered broadly, this great nitrogen readjustment was the most important chemical development of that period, the one most deeply freighted with meaning to the future of life on this globe. The breaking of Chile's natural monopoly was a dramatic episode which changed the course of that Republic's future. But it was more than this.

To replace, as a source of our nitrogen, the exhaustible natural deposit of sodium nitrate by fixed nitrogen drawn from the boundless stocks in the atmosphere * was to allay forever the horrible fear that an imminent dearth of nitrogenous fertilizers might starve out the human race or at least fix rigid limits to the population the earth can sustain. Sir William Crookes had posed this problem in 1893 in his presidential address before the British Association for the Advancement of Science. His startling statement has been so frequently misquoted that his exact words are of interest:

> It is difficult to get trustworthy estimates of the amount of nitrate surviving in the nitrate beds. Common rumour declares the supply to be inexhaustible, but cautious local authorities state that at the present rate of export, of over one million tons per annum, the raw material, *caliche*, containing from 20 to 50 per cent nitrate, will be exhausted in from 20 to 30 years. Dr. Newton, who has spent years on the nitrate fields, tells me there is a lower-class material, containing a small proportion of nitrate, which cannot at present be used, but which may ultimately be manufactured at a profit. Apart from a few of the more scientific manufacturers, no one is sanguine enough to think this debatable material will ever be worth working. If we assume a liberal estimate for nitrate obtained from the lower-grade deposit, and say that it will equal in quantity that from the richer quality, the supply may last, possibly, 50 years, at the rate of a million tons a year; but at the rate required to augment the world's supply of wheat to the point demanded 30 years hence, it will not last more than four years.
>
> The fixation of atmospheric nitrogen therefore is one of the great discoveries awaiting the ingenuity of chemists. It is certainly deeply important in its practical bearings on the future welfare and happiness of the civilized races of mankind. This unfulfilled problem, which so far has eluded the strenuous attempts of those who tried to wrest the secret from nature, differs materially from other chemical discoveries which are in the air, so to speak, but are not yet matured. The fixation of nitrogen is vital to the progress of civilized humanity. . . . Unless we can class it among certainties to come, the great Caucasian race will cease to be foremost in the world, and will be squeezed out of existence by races to whom wheaten bread is not the staff of life.[1]

Crookes' grim prediction of exhaustion of the workable *caliche* in Chile within "from twenty to thirty years" was obviously unwarranted,

---

* Above each square mile of the earth's surface float about 20,000,000 tons of pure N, sufficient, upon the basis of ordinary peacetime consumption, to supply world needs for 50 years.

and the probable life of the nitrate deposits since then has been much extended by both Chilean [2] and American [3] experts. Whether such deposits remain productive till 2000 or 3000 A.D., the problem worries us no longer. The human race might conceivably blast itself from the face of the earth with nitrogen-bearing explosives, but it will not be starved out for lack of nitrogenous fertilizers.

When Crookes made his startling statement on a problem then very real, he riveted the attention of chemists and inspired research for a practical nitrogen-fixation process. The first successes were scored in the United States early in the century, but for a variety of reasons commercial operation was not sustained and Norway took the lead.

In Germany this problem had a double meaning. To the Kaiser's militaristic clique, which foresaw a British blockade of Chilean saltpeter, nitrogen was as important for explosives as for fertilizer. So while Wilhelm II rattled his sword noisily for several years, he did not throw away the scabbard until the Haber synthetic-ammonia process and its companion, the Ostwald process for the conversion of ammonia to nitric acid, had been perfected and tested.[4] As an additional precaution, Germany built up a sizable stockpile of Chilean nitrate.*

No other nation was so prepared. Germany's opponents all depended for their nitrogen upon Chilean nitrate, eked out by varying supplies of by-product ammonium sulfate and some natural nitrogenous materials.† In the United States the growing imports of the prewar period showed that our dependence upon Chilean nitrate was becoming more and more complete. In all countries two facts stood out. First, the incomparably greater use of nitrogen was as plant food. Second, the bulk of this material was supplied by natural sodium nitrate from Chile. Roughly, four-fifths of the world's consumption of nitrogen went into fertilizers. Despite the growing output of by-product sulfate, Chile furnished two-thirds of this element.

In the United States, where farmers customarily buy complete mixed fertilizers, containing the essential plant-food elements nitrogen, phosphorus, and potash, three significant prewar trends were clearly indicated. American farmers were steadily increasing their use of fertilizer. The percentage of nitrogen in mixed goods was rising. The use of sulfate was increasing more rapidly than Chilean nitrate. On the other hand, chemical manufacturers intelligently avoided, so far as possible, direct competitive bidding for nitrate and ammonia as sources of ni-

---

* It is estimated her reserves of sodium nitrate were more than 500,000 tons augmented by 200,000 tons taken as booty in the capture of Antwerp. (See Crowell and Wilson, *How America Went to War*, p. 309.)

† For prewar consumption of Chilean nitrate and ammonium sulfate, see Appendix XIII.

trogen. Nitrate was the preferred material for conversion into nitric acid, while ammonia liquor was the favorite for the production of such staple chemicals as soda ash, ammonium chloride, sodium cyanide, ammonium nitrate, and household ammonia.*

As sole source of all nitric acid, Chilean saltpeter occupied a key position in chemical manufacturing. None of the several modern processes for direct oxidation of ammonia to this acid was then in operation in the United States, and our entire commercial output came from the distillation of a mixture of Chilean saltpeter with an excess of concentrated sulfuric acid usually in horizontal cast-iron stills.[5] This method had been perfected to a high-point-of-yield efficiency. It had the disadvantage, however, of carrying over the volatile impurities of the saltpeter and thus required further purification for fine chemical work. Its great commercial advantage was the important by-product, niter cake or acid sodium bisulfate.

While in this country, in 1914, very little nitric acid went into the production of organic nitro compounds, it was nevertheless an important chemical tool. Its chief uses were in nitrating cellulose, in the chamber-sulfuric acid process, and in glass-making. Then, as now, its greatest consumption was in the manufacture of industrial explosives.

At this time half the by-product ammonia was consumed in the manufacture of staple chemicals, but the fastest growing market was in refrigeration. Here, too, chemical manufacturers evaded competition for their raw materials by letting the ammonium sulfate produced at the by-product coke ovens go to the fertilizer mixers and drawing chiefly upon local gasworks for crude liquor for refrigeration ammonia.

Prior to the outbreak of the war in 1914, the consumption of nitrogen in the manufacture of military explosives had been insignificant. By early 1915, however, we were filling large orders for the Allied armies and thereafter requirements for explosives nitrogen grew rapidly. The munitions demand reached a maximum in 1918, when nearly 150,000 tons of nitrogen were so utilized. Throughout this tremendous expansion Chilean nitrate remained the only source of nitrogen and our imports mounted to record figures, jumping from some 772,000 long tons in 1915, to over 1,845,000 in 1918.†

Prior to the war, although the United States bought more than a quarter of the Chilean nitrate exported, American capital had but an inconsequential interest in this mining field. The deposits had originally been exploited on an international scale by the English, who remained in control. Germany was taking in over a third of the exports,

---

* For production of ammonia and ammonium sulfate, see Appendix XXI.

† For U. S. imports of Chilean nitrate, see Appendix XIV.

and while German farmers were constantly increasing their applications of nitrate fertilizers, a goodly proportion of German imports was re-exported for agricultural use to other European countries. As this profitable trade grew, German interests naturally wanted to extend their holdings in the nitrate field. They did this partly by securing direct mining concessions from the Chilean Government and partly by picking up small, unusually inefficient *oficinas.** The Chileans generally preferred to do business with the easy-going fair-minded English firms, but they were much impressed by the efficiency and vigor of German operations.

Back in 1884, it had been the local representative of a German house, Herman Schmidt, who had gathered together the nitrate producers in the first successful cartel-like organization to control production and raise prices.[6] Furthermore, German influence in administrative affairs, in operating techniques, and in local politics was greater than their actual share in the nitrate properties seemed to warrant. In the world markets, however, the British continued their control through the Chilean Nitrate Committee in London.

During the war the British employed this control, made by their Trading-with-the-Enemy Law, to shut down the German nitrate operations except for a few which evaded the British "black list" by transferring title to other nationals. After the war many German interests, properly impressed by the threat of synthetic competition, sold out their *oficinas,* so that by 1920, as William S. Myers, director in this country of propaganda for the Chilean Nitrate Committee, declared,[7] only three of the 51 nitrate mines owned in foreign countries were German, while 32 were English-owned. Until 1924, when the Guggenheim interests entered the nitrate field, American-owned *oficinas* never exported more than 2.5 per cent of the total sales. During the war American holdings were limited to properties of the Grace and du Pont interests. The du Pont Nitrate Company, which had been operating the "Oficina Delaware" in Taltal since 1913,[8] during 1917 increased its holdings by two large fields in the northern area acquired from the Chilean Government.[9] Du Pont production that year had been 35,000 metric tons; Grace, 42,000.[10] It was hoped the new properties would increase the American supply of saltpeter by an additional 50,000 tons annually. At no time during the war did an appreciable tonnage of the du Pont production reach the open market since the saltpeter was used almost entirely to make nitric acid for the Company's explosives.

---

* A Chilean term embracing a complete saltpeter mining and refining enterprise, though commonly limited in meaning to the plant, not the mines.

Prior to 1916, W. R. Grace & Company did not engage importantly in nitrate production. Its subsidiary, Nitrate Agencies Company, Ltd., acted as shipping, purchasing, and financial agents and general administrators not only for Grace, but also for several British-owned properties, whose total monthly exports averaged 11,000 tons. From a modest start in 1909, this organization grew to be one of the most powerful in the nitrate business, operating warehouses, docks, and lighters to load nitrate and handle incoming freight. In 1916 the parent firm in New York incorporated the Grace Nitrate Company which purchased the splendid property of the Tarapaca & Tocopilla Nitrate Company from English owners for $3,000,000. Its up-to-date *oficina*, the "Papaso," had the first installation of Burt pressure-filters, a working unit that embodied the ideas of the Company's engineers and Charles Butters & Company. With a pay roll of about 1,000, the output averaged 4,000 tons monthly. This was the most important American-owned nitrate enterprise.[11]

Before the war the nitrate market in the United States had been strongly held in a few hands.[12] W. R. Grace & Company long maintained a dominating position. As a part of its general trading business and its freight-carrying steamers to various South American ports, this company never failed to bring in more than half of the saltpeter used in the United States. After enjoying a virtual monopoly for several years, Grace was challenged by Wessel, Duval & Company, an American partnership with English connections that controlled extensive mining operations in Chile. To obtain a foothold, the newcomer was forced to cut prices and for several years competition was so keen that big, shrewd buyers, by playing one seller against the other, were able to purchase nitrate below cost.

From time to time another English firm, Balfour, Williamson & Company, which carried on an international trade in vegetable and fish oils, dyewoods, and natural tanstuffs, attempted to elbow its way into the American nitrate trade. Temporarily the market was upset, but the established importers made common cause against the invaders and their efforts were never permanently successful. Late in 1913, however, H. J. Baker & Bro. of New York, one of the leading brokers of fertilizer materials, made a favorable nitrate sales-agency agreement with Antony Gibbs & Company of London. After several months of price war, it won a toehold in the market. Amid the commercial havoc of the war period, Baker was able to consolidate a firm position. From time to time two large consumers, the American Agricultural Chemical Company and the Armour Fertilizer Works, imported nitrate purchased in Liverpool, Hamburg, or Valparaiso.* These occasional, direct importations were mainly a gesture warning regular importers to keep prices in line with world markets.

This price, set in London, was based upon the continental market where nitrate fertilizer consumption was heaviest and competition with ammonium sulfate most direct. Nitrate prices both in the United States and Chile followed London quotations. Accordingly, the heavy planting of sugar beets throughout Europe in 1912 (due to high world prices for sugar in 1911) initiated a world-wide advance in nitrate prices. This was encouraged by a shortage of shipping, by high charter rates, and by coal strikes in England which cut down ammonium sulfate output. Nitrate prices moved up, stocks were depleted, and for the first time in several years the visible supply in all markets at the end of 1912 was less than the year before.[13]

By March 1913, however, the pendulum swung the other way. High prices encouraged production and high ocean freights, the building of more ships. Charter rates dropped rapidly and the nitrate market became again overstocked. When Gibbs invaded New York the price fell as low as $2.075 per hundred pounds, which was below current quotations in Liverpool.[14] So heavy were the overstocks at all important consuming centers that even the outbreak of the war did not stiffen nitrate prices.

Anybody could figure that war explosives would create a big, fresh demand. Nobody suspected how great that demand would be. Moreover, everyone knew that production in Chile had been stimulated to such record quantities that during the fall, when Germany customarily took in great stocks for her fertilizer trade, the diversion of these cargoes to other ports piled up what appeared to be a staggering surplus. Prices fell during the winter of 1914-15 and two-thirds of the *oficinas* shut down. Chile had a real unemployment problem on her hands.[15]

* "From 1913 to early 1916 the Armour Fertilizer Works maintained a salaried resident nitrate buyer in Valparaiso, and he purchased the bulk of their Southern states, Cuba, and Porto Rico requirements. This was the way it was handled. Armour's London bankers were Frederick Huth & Co. They had a branch bank in Valparaiso. Our representative, Otto Riall, a naturalized German-American—who also acted as an Armour scout and inspector—on receiving a list of our requirements and deliveries would purchase from time to time what were called 'strings,' or futures, calling for the delivery of so many tons a month at certain ports. These purchases were made from different sellers. These strings were negotiable. Our Valparaiso bankers handled the finances. We would then advise our London banker of our purchases and delivery dates. They chartered ships to carry coal to Chile from England, sold the coal to a nitrate producer, loaded nitrate for the states, generally for a two-port delivery, and after discharge took on a cargo of cotton for England. This procedure enabled us to secure cheap charters and we found the method profitable. We discontinued our buying office early in 1916: Our representative had a fist-fight on a tram car with the British consul general and we deemed it wise to recall him." (C. H. MacDowell, to author, Nov. 4, 1942.)

By April 1915, however, munitions demands turned the depression into a boom. Prices rose and production, feverishly expanded, reached a peak. Within a year the entire Chilean industry was humming with activity. The record production of all time, 3,013,517 metric tons,[*] was established in 1917.

During that year of record output, however, shipments were curtailed by strikes in Valparaiso at the nitrate ports of Antofagasta, Iquique, and Mejillones.[16] These disturbances, which spread to the northern nitrate fields themselves, were accompanied by noisy political agitation suspected to have been fomented by professionals, well paid by German interests—a sort of elementary trial of the fifth-column technique perfected in World War II.

Despite the great increase in output, supply never overtook demand throughout the war period, and nitrate prices reacted in natural response to the old economic law. The advance which started in November 1915, was initiated, curiously enough, by the prospective demand for next-spring fertilizer markets. Thereafter, however, the nitrate of soda price, urged on by the insistent call of the munitions makers for "More! More! More!" climbed without faltering until the signing of the Armistice in 1918.[†]

The New York price quotations are deceptive. They are the asking price of direct importers for spot material. From the middle of 1916 onward, these quotations were often merely "nominal," for firsthand dealers were frequently without stocks to fill current orders. Accordingly, a lively trade was carried on both here and in Chile by secondhand speculators who reaped exorbitant profits on the actual delivery

---

[*] The Chilean nitrate statistics (metric tons) for this period is given by the *Internat. Crop Rept. & Agr. Statist.* (Rome), Sept. 1916 & Sept. 1917, as follows:

	1913	*1914*	*1915*	*1916*	*1917*
Production	2,773,552	2,464,427	1,763,639	2,914,542	3,013,517
Exports	2,739,530	1,847,586	2,031,014	2,991,786	2,787,339

[†] Average Wholesale Prices (New York) for Nitrate of Soda

Year	*Per 100 lb. nitrate*	*Per ton nitrogen (15.6% N)*
1912 [a]	$2.44	$313
1913 [b]	2.32	298
1914 [b]	2.12	272
1915 [b]	2.33	299
1916 [b]	3.18	480
1917 [b]	4.05	519
1918 [b]	4.68	600
1919 [c]	3.61	463
1920 [c]	3.52	451

[a] Fed. Trade Comm., *Report on Fertilizer Industry,* 1916; [b] War Ind. Bd., *Price Bull. No. 48;* [c] *O.P.D. Reptr.*

of spot material. This lucrative speculation was greatly fostered by the irregular and uncertain shipments arising from the shipping crisis.

The German High Command may have erred dangerously on the low side in calculating its own nitrogen requirements. It did not, however, make the mistake of underestimating the nitrogen needs of the enemy. No doubt Germany was blockade-conscious, for in the early stages of the war it took extraordinary risks and paid a high price to interfere with the Chilean nitrate trade.

When England declared war early in August 1914, the German Far East Fleet was scattered throughout various Chinese and Australian stations, the commander, Admiral von Spee, with the modern cruisers *Scharnhorst* and *Gneisenau*, being off the Solomon Islands. Somewhere in the vastness of the South Pacific, seven of his best ships made rendezvous, and he detached two of the fastest, the *Emden* to the Indian Ocean and the *Karlsruhe* to the South Atlantic. With the five others he appeared off the west coast of South America early in October and immediately began systematically raiding the nitrate freighters northbound from Chilean ports to the Panama Canal.*

On November 1, off Coronel, von Spee encountered three British light cruisers and a converted merchantman commanded by Admiral Craddock who had rounded the Horn and was seeking to locate the raiding squadron. Though outclassed in speed and armament, Craddock attacked, but disastrously, for the longer range of the German guns enabled them to batter the British ships almost with impunity. Craddock went down with his flagship. The *Good Hope*, and the *Monmouth* also sank with all hands. The two smaller British ships escaped in the darkness of a stormy night. For another month von Spee continued to ravage the nitrate fleet. He established so complete a control over the Chilean coast that British cargoes became uninsurable and nitrate shipments were practically suspended.[17]

December 6 von Spee sailed through the Straits of Magellan, intending to destroy the British coaling station in the Falkland Islands and so make his own position off the west coast more secure. Here he ran unexpectedly into a powerful British squadron. Without hope of victory or chance of escape, he and his sailors and his ships were lost.†

* "One matter of greatest concern was the availability of the Panama Canal, which had been opened to traffic but was so subject to slides that it was not officially opened; in fact, the official opening did not occur until 1921. I believe that all of our vessels leaving Panama had instructions to proceed to the West Coast of North America in case they found the Canal closed. Arrangements were made to ship the cargo to the East Coast by rail. This was actually done in the case of one cargo." (Pierre S. du Pont, to author, Nov. 4, 1942.)

† Winston Churchill, then First Lord of the Admiralty, has written a vivid account of the Battles of Coronel and the Falklands in *The World Crisis*, pp. 232-52.

The annihilation of von Spee's fleet cleared the seas of the last German commerce-destroyers. The nitrate trade was reestablished and the route from Chile to our Pacific and Atlantic ports remained uninterrupted throughout the war. Even after the Pacific was swept clean of German raiders, however, the nitrogen supply problem of the Allies was not solved. As the war progressed, it became more and more acute.

The crisis was reached during the winter of 1917-18, when things were not going well for the Allies on the Western Front. Germany was making supreme efforts to break the deadlock of the trenches before the American reinforcements in men and munitions could be landed in France.

In December 1917, ships were allocated to the Nitrate Section of the War Industries Board to handle all January, February, and part of the March purchases of Chilean nitrate. During the same winter of 1917-18, a number of ships were diverted to transporting coal to New England, which threw the shipping schedules out of gear, so that at one time less than six weeks' supply of nitrate was on hand.[18] To meet this situation, inventories were studied, stocks were borrowed, and by transferring from one acid plant to another, all were kept running at capacity.

At the very time we were hardest pressed, both the French and Italian armies were crying for ammunition, and the success with which the Germans were furiously pushing their submarine campaign made it particularly hard to keep the European explosives plants of our Allies supplied with necessary nitrate. At the same time we were pouring thousands of troops with their equipment and provisions across the Atlantic. Every available ship was needed. The fact that in June 1918 the "nitrate fleet" consisted of 105 steamers and 23 sailing vessels [19] shows at once how imperative was the need for this raw material and what a serious strain it put upon Allied shipping resources. During those dark days the U-boats scored several lucky bull's eyes, sinking nitrate ships off the coast of France and even in the English Channel.

Word came from France that a German drive was expected in early March and that submarine sinkings had reduced French nitrate stocks to a dangerously low point. At least 75,000 tons were needed at the earliest possible moment. The British could send only a small tonnage, but we diverted 12,000 tons of incoming Navy nitrate and loaded it on the *Texas*. This boat was rammed in convoy and had to return for repairs. Another burnt in Halifax harbor under suspicious circumstances. The Nitrate Section, under MacDowell, commandeered a Grace Line steamer at the Panama Canal, as well as some 42,000 tons of the Agriculture Department nitrate,* thus saving the French explosives factories from actual shutdown.[20] Later, the tension was to be relieved somewhat, but from first to last the supply of nitrogen was our chief chemical worry.

REFERENCES

1. *Proc. 68th Ann. Meeting*, pp. 16-18 (1898).
2. F. J. Castillo, Inspector General Nitrate Deposits, off. rept. to Chilean Govt., 1913, quoted in *Final Report of Nitrogen Products Comm.*, Ministry of Munitions, London, 1920, p. 222; J. A. H. Clark, *Bull. Pan-Am. Union 47*, 645 (1918).
3. G. R. Mansfield, "Economic Geology of Fertilizer Minerals," in *World Conditions as to Mineral Raw Materials for Fertilizer Industry*, p. 13; H. F. Bain and H. S. Mulliken, Bur. For. Dom. Com., *Trade Inform. Bull. No. 170*, 69 p.; F. A. Ernst and M. S. Sherman, *Ind. Eng. Chem. 19*, 196 (1927).
4. *Drug Chem. Mkts.* 4 (Aug. 15, 1917).
5. Read, *Industrial Chemistry*, p. 184. Detailed contemporary description of process in Chap. 5 by W. M. Grosvenor, in Roger's *Manual of Industrial Chemistry*, 4th ed., 1925.
6. Russell, *A Visit to Chile*, pp. 328-34.
7. Hearings Subcomm. No. 5 (Ordnance) Select Comm. Expend. War Dept. (House 66:3), Feb. 7, 1920, p. 3541.
8. *Com. Fin. Chron.* 860 (Mar. 22, 1913).
9. *Min. Ind. 1917*, 631; *O.P.D. Reptr.* 33 (May 7, 1917).
10. *Drug Chem. Mkts. 6*, 1041 (1920).
11. Clark, *op. cit.; O.P.D. Reptr.* 15 (Oct. 30, 1916).
12. Fed. Trade Comm., *Report on Fertilizer Industry*, 1916, p. 29.
13. Fed. Trade Comm., *op. cit.* p. 126.
14. War Ind. Bd., *Price Bull. No. 45*, 12.
15. *Met. Chem. Eng. 13*, 76 (1915).
16. *Drug Chem. Mkts.* 15 (Sept. 12, 1917).
17. G. Jones, *Quart. J. Econ. 34*, 399 (1920).
18. Baruch, *American Industry in War*, p. 169.
19. Nitrate Div. (Ordnance), *Report on Fixation and Utilization of Nitrogen*, 1922, p. 23.
20. Clarkson, *Industrial America in World War*, p. 394.

* "Southern senators and congressmen heard from their constituents and North Carolina members sent a large delegation (some 40) to see me. When the problem and its solving was explained to them 'in confidence' (the danger point had passed) they agreed we had handled the problem properly." (C. H. MacDowell, to author, Nov. 4, 1942.)

Chapter 7

NITRATE SPECULATION AND SUPPLIES

NITRATE PRICES RISE 300 PER CENT ON U. S. DECLARATION OF WAR—WAR INDUSTRIES BOARD BUYS DIRECT TO HOLD PRICES—INTERNATIONAL NITRATE EXECUTIVE TAKES OVER ALL ALLIED PURCHASING—GERMAN SABOTAGE IN CHILE—CHILEAN NITRATE PRODUCERS' MONOPOLY BROKEN.

EARLY in 1917, it was quite evident that the United States would be drawn into the conflict, President Wilson having broken diplomatic relations with Germany, February 3, 1917, upon her resumption of unrestricted submarine warfare. Speculators, who were watching every turn of events with eagle eye, began quietly accumulating nitrate for future delivery. They anticipated that to munition the American Army would enormously increase demand and, knowing that output was already insufficient to go 'round, they foresaw a sharp price advance. This came immediately upon the declaration of war, and when it became clear that the United States was to be no passive ally, but would send a big expeditionary force to the battlefront, the price soared.[1] By the end of April the spot price for immediate delivery reached 7½¢ a pound, an advance of 300 per cent over normal, although the open-market, published price at the time was 3.75¢.

Official purchasing agents for the English and French began buying frantically. Congress had made no appropriation for munitions purchases, nevertheless American explosives makers also scrambled into the market, attempting to cover their prospective, future requirements. This wildcat business was neither to the liking nor advantage of the established importers, and both in London and New York the old houses did their best to apply brakes to the market. But the temptation to grab extra profits was greater than the producers in Chile could withstand. They, too, began advancing their quotations for autumn delivery, so that Baruch with Summers, who was handling all chemicals for the Raw Materials Division, foresaw a pyramiding of prices that would get completely out of hand. Better than any two men in the world, they knew the munitions plans being drawn and realized the huge additional demand that would be created in this country when the Government called for bids for high explosives and powder. Something drastic must be done and done quickly.

Senator Ellison Smith came to Baruch with an appropriation of $10,000,000 to buy nitrate for distribution to farmers at cost through the Department of Agriculture.[2] In 1917 the farm bloc was not the closely knit, formidable pressure group it was to become during World War II, but it is interesting to note that Congress voted this tidy sum to farmers' aid before it provided appropriations for military explosives. The energetic and prompt way in which the Senator from South Carolina acted has since become very familiar in Washington. An active cotton planter himself, who had organized the Southern farmers to fight the boll weevil in 1905, Smith went to the President to get action for his constituents and to secure a lower price for fertilizer nitrate through Executive influence.

Wilson told him plainly that Baruch was the only man, and the Raw Materials Division the only government agency that could help him buy nitrate of soda in Chile or anywhere else.[3] Quite informally and without any legal justification the President thus extended Baruch's authority to control over raw materials for agriculture. This display of confidence foreshadowed the creation of the War Industries Board with Baruch directing the full economic resources of the country. No doubt Baruch sensed this. Certainly he did not need to be convinced that some such centralized control was necessary. This fertilizer appropriation immediately suggested to him that the Government might also buy nitrate for explosives and distribute it at cost to the munitions makers. He called in Summers who proposed a daring course of action.

Having learned his way through the tricky mazes of the international nitrate trade while working with the British Purchasing Commission, Summers realized that the only way to check the mounting speculation was to knock the props from under the market. He recognized instantly the enormous leverage that could be exerted by pooling all American purchasing in a centralized government agency, and he was willing to gamble boldly that this power could in some way be made effective.

"Not only should the Government buy nitrates for all American needs," he agreed, but he added, "Let us sell explosives makers their requirements to fill their government contracts at 4½¢ a pound, delivered in New York."

Neither Baruch nor Summers had any idea how they could make good this price. Indeed, at the time it was more a threat to the speculators than a promise to consumers. Both men were confident that some way could be found. If worse came to worse, it might in the end become merely a problem in simple arithmetic, since explosives contracts were being let on a cost-plus basis and there were well-known, accepted ratios of nitrate to nitric acid and acid to explosive. Any bookkeeper could figure the allowance to be credited on every pound of explosive delivered for any cost above 4½¢ paid out by the manufacturers for saltpeter. The accounting would be so straightforward that there would be little opportunity for fraud. Even if the scheme did not check advancing prices, it would cost the Government nothing, since in the end it made no difference how the costs of finished explosives were allocated on the books. If price advances were checked there would be enormous savings. Apparently there was everything to gain and nothing to lose.*

Gleefully, these two conspirators went to work. Baruch announced that on government contracts explosives makers could figure a nitrate cost of 4½¢. Summers very obviously became much interested in nitrogen from the air, which he discussed avidly with all his visitors, dropping broad hints about adapted and improved processes and government-built plants to operate them.

With definite assurances of a lower price, munitions makers stopped their frantic bidding and the price of nitrate stopped its upward swing. Both speculating middlemen and producers in Chile were worried. They could not figure how the Raw Materials Division could secure nitrate to make delivery at any such price, but this very uncertainty created a mystery that fed their anxiety. Baruch and Summers were worried, too, until the Navy Intelligence Division gave them confidential information which was a passkey to their problem.

One result of the wholesome respect Chileans had for German methods and ability and of the political influence German residents wielded in Chile, had been the deposit of $17,000,000 of the Republic's gold reserve in Berlin. All belligerent nations had placed gold under embargo, and due to her heavy purchases abroad, Chile's available gold reserve supporting her paper currency became dangerously thin. The Chilean Ambassador in Berlin, therefore, applied to the German Government for permission to transfer his Government's $17,000,000 deposit to Holland, Switzerland, or any other neutral country, whence it could be returned to Santiago. This request was promptly and unequivocally refused.

These abortive negotiations, picked up by our Navy Intelligence officers, were seized upon by Baruch to suggest to the President of Chile, through diplomatic channels, that it would be quite proper retaliation for his country to confiscate the German-owned stocks of nitrate within its borders. He added that if this were done, the United

---

* Both Baruch and Summers told this story at the hearings (House 66:1-3) of the Graham Comm. investigating expenditures in the Ordnance Dept. (Subcomm. No. 5), 1920, pp. 3014, 3795. See also Baruch, *American Industry in War*, p. 358; Clarkson, *Industrial America in World War*, p. 390.

States Government might be persuaded to relax its embargo and buy the confiscated nitrate for gold at a price that would restore the Chilean reserve. So simple an escape from the impending financial crisis was welcomed by the Chilean Government. The purchasing power of its peso was fast vanishing; its people were dependent upon imports for even more of their fuel and food; a ruinous inflation was threatening. The agreement—American gold for German saltpeter—was quickly concluded.

German nitrate operations had been much curtailed for lack of fuel oil and jute bags from which they had been cut off by the British Trading-with-the-Enemy Act. Stocks had piled up at their *oficinas* because the British-controlled railways, for the same reason, would not accept shipments from German companies. In this way 235,000 tons of nitrate had accumulated at the German refineries.[4] This was sufficient saltpeter to restore the Chilean gold reserve at a price of less than 4¢ a pound.

It was necessary, however, to obtain from the British Government releases of jute bags in Calcutta and suspension of their Trading-with-the-Enemy Act to permit the use of certain railways, warehouses, and docks at the nitrate ports. These arrangements, which were carried on in great secrecy, brought Baruch in touch with Winston Churchill, who had recently been shifted from the Admiralty to the Ministry of Munitions in the British Cabinet, and this contact led to an active co-operation between the two which made the effects of this nitrate coup more impressive and lasting. Not only did Churchill expedite the necessary arrangements for the delivery of this German nitrate to the United States, but he further agreed that the British Government would hold up its purchases of nitrate during October, November, and December.

These three months were a crucial period. The last quarter of the year had always been the time of large fertilizer-nitrate shipments over against the spring planting season ahead. In 1917 this coincided with the time when British and French explosives plants were working overtime to pile up a reserve in anticipation of the German spring offensive and when, furthermore, the new American munitions demand would come into the market. Shrewdly the international speculators had tied up as much nitrate as possible for delivery during this period.

Just when these clever gamblers expected to cash in, the established dealers in New York—through whom the Raw Materials Division had imported the German stocks—upset their calculations by offering the confiscated nitrate at 4½¢, the price that Baruch had promised the munitions contractors. Simultaneously, the British Government let it be known that it was out of the market. Nobody outside knew exactly what had happened or how much material the Raw Materials Division controlled. It was noised about that it had secured big quantities confiscated from the German *oficinas*. Wild rumors exaggerated the dismay of the middlemen and the producers who began unloading their stocks. Chile was thrown into a panic, which further broke the price. Neither the United States nor Great Britain wanted to see the legitimate Chilean industry disorganized or the Chilean people hurt, so the Raw Materials Division notified the Chilean Government that it would purchase for the combined account of all the Allies any nitrate offered in Chile during this quarter at the same price paid for the German confiscated stocks. This was 10 shillings, 5 pence per quintal or a little below 4½¢ a pound.*

In the midst of this tumultous climax Charles H. MacDowell came to Washington to take charge of nitrates for the Raw Materials Division. He was president of the Armour Fertilizer Works, an experienced, decisive executive, thoroughly familiar with the nitrate trade, well qualified to carry out the plan which was being evolved in negotiations at London between Great Britain, France, Italy, and the United States. It had been made painfully evident that, if a steady supply of nitrates was to be maintained at a reasonable price, the Chilean-producing monopoly must be dealt with through a single Allied purchasing body. The representatives of the four Allied nations, therefore, set up the machinery for such a buying pool. The United States was represented by Chandler P. Anderson,[5] a lawyer who, as former counselor of our State Department, was wise in the ways of international diplomacy and enjoyed a wide, personal acquaintance among ranking officials both in London and Paris.

Out of this conference grew the International Nitrate Executive, organized in December 1917, which, after the first of the year, bought all Chilean nitrate for the four Allies and distributed stocks among them

---

* "I have no final figures as to the price paid the Chilean Government for the German nitrate as the transaction was kept a deep secret. According to my notes the gold on deposit in Berlin by Chile was valued at $16,000,000, not $17,000,000 as has frequently been stated. The tonnage, all grades, was estimated roughly as 235,000 Chilean tons. Using $16,000,000 and assuming it was all used for the nitrate purchase, the price per ton figures out at $68.08 for 20 quintals of 2028.32 lb. Deduct an estimated $12.50 export tax to enable one to compare the price with the open Chilean market, and one arrives at $55.58 for 20 quintals, or $2.779 per quintal, or say 11 shillings 5 pence, figuring the pound at $4.86. Baruch, in *American Industry in the War*, 1921 ed.–his final report–page 390, states 'the price offered being about 60% of the current market.' Although Becker could not check sales above 15 shillings 6 pence, it was stated that 17 shillings had been paid for fall 'strings' ordinary. This would make the price in Chile, before export tax, around 10 shillings 5 pence at 60% of current market. There would have been no reduction of current market if 17 shillings had been paid. This figures out 4.13¢ for 1.0141 lb. in Chile before export tax, freight to U. S., and other charges." (C. H. MacDowell, to author, Nov. 4, 1942.)

WILLIAM S. MYERS

DONALD RILEY

H. RAY PAIGE

F. MORSE SMITH

according to their necessities.[6] This international purchasing pool was headed first by Sir Edmund Wyldbore-Smith,[7] the director of Allied purchasing, and later by Herbert Gibbs [8] of Antony Gibbs & Company. After its organization, the United States representative was the consul general in London, Robert P. Skinner. In this country the International Nitrate Executive functioned through the Nitrate Section of the War Industries Board.* MacDowell remained the chief of this important section even after he became director of the entire Chemicals Division of the War Industries Board. To assist him, he brought to Washington an old business associate, John A. Becker, traveling auditor of the Armour Fertilizer Works. MacDowell also established an office in New York with H. Ray Paige, president of H. Ray Paige & Company, New York brokers, as manager to supervise and coordinate the operation of the established nitrate dealers through whom it was decided to import and distribute.

It was originally planned that the Nitrate Executive in London would buy direct in Chile. This procedure would have definitely eliminated the speculators. But it would have also cut out the legitimate importers and involved the handling of all the financing and shipping details. The brilliant Baruch-Summers maneuver had been executed through the established nitrate firms in New York, which had bought the confiscated German nitrate; paid for it with gold specially released by the Treasury Department; arranged for the shipments; sold and delivered it in the open market at the determined price.

So satisfactory were the results, that they presented a strong argument for continuing and extending similar arrangements for handling the business of the Allied buying pool. Accordingly, the Nitrate Executive placed orders for this country through Paige in New York, to be executed by the four established importing houses acting as sole purchasing agents for the Allies.

Two representatives for each of these firms—Harold J. Roig and F. G. Fisher for Grace, J. B. D. Edge and W. Arthur Murphy for du Pont, George L. Duval and Paul W. Alexander for Wessel-Duval, and F. Morse Smith and B. C. Chamberlin for Baker—formed a Nitrate Committee. Duval served as chairman, and Paige, as representative of the War Industries Board, was the active office manager. Upon the basis of their average prewar importations, these representatives agreed

---

* Coordinating members of the Nitrate Section were: *Army*, Lt. Col. W. C. Spruance (formerly with du Pont, an explosives expert) and Maj. W. H. Gelshenen, who generally represented the Army in chemical matters; *Navy*, Lt. Comdr. Donald Riley (B.S., U. Wis.; Ph.D., Berlin 1915, chem. engr. with Koppers and after the war, with Armour Fertilizer Works and vice-pres., Chicago Title & Trust Co.) in charge of chemicals for the Navy, and Ensign C. C. Grimes; *Shipping Board*, E. F. Gay, statistician, and Dr. C. H. Creith (U. Wis.), geologist.

among themselves that of all the nitrates allocated by the international pool to the United States, W. R. Grace & Company should handle 36.66 per cent; the du Pont Nitrate Company, 33.33 per cent; Wessel, Duval & Company, 11.33 per cent; and H. J. Baker & Bro., 18.66 per cent.[9]

All prices were pooled and averaged, and deliveries were made only as the War Industries Board directed. On direct government business the four importing agents received the cost of nitrate plus only their actual expenses. On outside sales they agreed to accept a uniform, gross commission of 2.5 per cent.[10] The Committee, as a whole, calculated prices, assigned cargo space, allocated available material so as to keep manufacturers in the essential industries supplied, and reported regularly to London in order that the Nitrate Executive might be continually informed on American requirements and conditions.

Terms of the customary trade contracts for the sale of nitrates for future delivery were quite inapplicable to war conditions and the control of supply and prices by the War Industries Board. The Committee, therefore, drafted a new standard form.[11] While this followed the general outline of the old sales agreement, it had several novel, arbitrary provisions born of the emergency. No shipments or deliveries could be made in any way contrary to the instructions of the War Industries Board and resale by any purchaser was flatly forbidden. Payment was to be made in full upon delivery, without cash discount. Furthermore, the seller had the right to deliver the ordinary 95 per cent material if the 96 per cent refined grade was not available. In event of any dispute arising between buyer and seller, the War Industries Board was to be the sole and final arbiter.

Calculating American prices was one of the most important and difficult tasks of the Nitrate Committee in New York. Month by month the Nitrate Executive in London established the price in Chile by averaging the cost of all its purchases during the preceding thirty days. Upon this base price, the Committee calculated the monthly price delivered in warehouse at American ports by adding to the Chile price the average ocean freight, insurance, dock and demurrage charges. Even after the Shipping Board simplified these calculations, by setting uniform ocean freight rates from various nitrate ports in Chile to the various receiving ports in United States, the computation of the landed price here was exceedingly complicated. Final figures could never be determined quickly enough to enable importers to bill at the time of delivery. Accordingly, a tentative price had to be used with the understanding that when the final cost had been found, refunds would be made. From January to April 1918, bills were rendered, some at the tentative price of 4.25¢, others at 4.35¢; but from May forward, the

Committee announced a temporary price each month.[12] At no time during the control of prices by the international pool, that is, from February to September, did the final landed price reach the 4½¢ per pound Baruch had promised. The top figure was $4.2900512 per net hundredweight (February) and for five of the eight months the final price was below $4.00 per hundred.*

Against the record speculative price of 7½¢ or $150 a ton, these prices showed a savings to this country of roughly $67.50 a ton on over a million and half tons imported during the eight months that the Allied purchasing pool was in operation. The actual savings were certainly more than $18,000,000. This is an impressive sum, yet the price paid showed the Chilean producers a very handsome profit. It also included over $15,000,000 paid by us in export taxes to the Chilean Government. Upon the basis of wartime costs, Zanetti [13] has estimated that the Chilean production costs were $27.50 a ton. Hobsbawn [14] is even more conservative and sets the cost figures at only $25.50 per long ton of 96 per cent grade, f.a.s. Chilean ports. To either figure must always be added the export tax of $12 a ton.

The acid test that this price was high enough to stimulate the maximum possible production, came when the Chilean Government offered a special, even lower price on 680,000 tons of nitrate, accomplished by a partial remission of the export tax, provided that the War Industries Board would arrange to pay in locomotives and freight cars, coal and fuel oil, and jute bags needed by the *oficinas* to maintain their output. Again Baruch and Churchill went to work together to put through this curious reversal of their former negotiations with the Chilean Republic.

Throughout the war the nitrate situation was complicated by a warm pro-German feeling which flourished throughout Chile. German residents there were numerous and some of them were in very influential positions. They made the most of every chance to nourish these sympathies. The British Trading-with-the-Enemy Act, by interfering with the normal, profitable foreign trade, was good food for growing resentment against the Allies. The German sympathizers did not stop at propaganda and sabotage. They made a bold attempt, in June 1918, to tie up production at the British *oficinas* by legal action.

The German nitrate-producing companies joined in a suit against certain English trading companies to recover large quantities of fuel oil contracted for before the war, delivery of which had been interrupted by the Trading-with-the-Enemy Act. A friendly court granted an injunction forbidding the English firms to deliver oil to anyone else until the quantity due under these contracts had been given to the Ger-

---

* For these tentative and final nitrate prices, see Appendix XV.

man claimants. Since there had been a gradual change in fuel at the refineries from coal to oil,[15] much of it from California, this injunction threatened to paralyze a sizable output. Coached by the War Industries Board, the American petroleum companies broke this deadlock by indicating that they would ship no more fuel oil to Chile until this injunction was removed. In the common interest the Chilean Government set aside the court action.[16] Thereafter German sympathizers made no public, concerted moves to disrupt the nitrate trade.

In spite of the popular pro-German sentiment, most Chileans, viewing the war with cool realism, made hay while the sun was shining and turned out a record production to meet the abnormal demand. The prosperity of the entire country was bound up in the nitrate trade, and thanks to the nitrate export levy, the people, rich and poor, lived virtually tax-free while their Government had ample funds for its current expenditures, even for public improvements. The happy lot of this "nitrate nation," the envy of all South America, was fated to be rudely disrupted by synthetic nitrogen from the air. During the heyday of the war, however, nobody in Chile anticipated the ruinous troubles ahead.

In 1918 we brought in from Chile almost three times as much nitrate of soda as we had ever imported before the war. During that year, the peak of our war effort, it is estimated that we consumed in the manufacture of military explosives 151,000 tons of the element nitrogen, 135,800 tons from nitrates and 15,200 tons from ammonia. This required 870,000 tons of sodium nitrate from Chile and 18,800 tons of ammonia equivalent to 74,000 tons of ammonium sulfate.* This was a greater quantity of sodium nitrate than we had consumed for all purposes—fertilizers, chemicals, military and industrial explosives—in any prewar year.

By literally robbing the American farmer of nitrate plant food and by doling out sodium nitrate and ammonium sulfate most parsimoniously to all non-munitions industries, we were actually able, during the latter part of 1918, to build up a modest reserve to meet unexpected emergencies. At the close of the year we had a stockpile of some 600,000 tons of saltpeter which, plus a small stock of ammonium sulfate (used in one process for manufacturing ammonium nitrate), gave us a reserve of some 80,000 tons of available nitrogen.

At the same time military needs were growing incredibly. It was estimated by the War Industries Board that in 1919 we would require 2,321,086 gross tons of sodium nitrate, 1,890,562 tons of which would

---

* Estimates based on data by Lt. Comdr. Carleton H. Wright, *Proc. U. S. Naval Inst.* Oct. 1920.

be used for military explosives.* It was conceded impossible to increase materially the 1918 imports of 1,500,000 tons. The output in Chile was being pressed to the top limit of available labor and refining equipment. No more ships could be diverted to the nitrate fleet. The nitrogen situation was quite as desperate as in the spring of 1918.

Before we entered the war, the Geological Survey had explored the possibilities of a domestic supply of natural nitrates. As early as 1916, it had prospected the most promising deposits of sodium, potassium, and calcium nitrate in southern California.[17] Furthermore, private prospectors, stimulated by the high prices, scoured all likely locations in the West and Southwest. In Colorado a deposit was found that for a few weeks created a mild sensation.[18] Even in the highly favorable war market, however. not a single one of all these deposits proved out rich or extensive enough to warrant commercial exploitation. During 1917 the American Nitrate Company spent $140,000 exploring and assaying several deposits in southeast Oregon, but was eventually forced to this same conclusion. There was no reasonable hope of finding any domestic supplies of natural nitrates to relieve the situation.

During 1917-18 there was an almost miraculous expansion of the production of ammonium sulfate from by-product coke ovens.† Against this we had lost our sizable imports of this material from England. More ammonia was also being recovered at our gasworks, but the total of all these by-product sources of nitrogen was only a small fraction of the critical need. From the very first Summers and MacDowell, who knew the facts, realized that the ultimate solution of the nitrate problem lay in the manufacture of synthetic nitrogen. They faced these facts, and the whole nitrates program of the War Industries Board was, therefore, predicated upon filling the gap with Chilean saltpeter until such plants could be built and brought into production.[19]

The abrupt, unexpected ending of the war, November 1918, lifted the nitrate incubus from the shoulders of the Allied Nitrate Executive and dropped it into the lap of the Chilean producers. Their capacity, already at a high peak, was augmented by a resumption of operations at the German-owned *oficinas*. Surplus munition nitrates, especially in the United States, were thrown on the market. The buying power of European farmers was low. Finally, the threat of synthetic nitrogen began to be a reality. All three elements in their crisis adjusted themselves in time to the new conditions; but nitrogen from the air, pro-

---

* In its 1916 *Report on the Fertilizer Industry* (p. 29), the Fed. Trade Comm. had estimated that in 1913, 40-55% of the Chilean nitrate imported went into fertilizers, 10-20% into chemicals, and 35-40% into explosives, chiefly industrial. For 1918, the War Ind. Bd. records showed that 61% was consumed in munitions, 17% in fertilizers, 12% in chemicals, and 10% in commercial explosives.

† The expansion contracted for by the Ordnance Dept. is shown in Appendix XX.

duced at lower cost, was a new, unavoidable competitor destined to abolish their ancient monopoly.

Led by the British mine owners, the producers acted promptly and vigorously. In January 1919, they revamped their old association, organized to carry on educational work in the fertilizer field, into a cartel.[20] A strong executive board, two members of which were representatives of the Chilean Government, rounded up the producers, threatening to shut down non-cooperators by withdrawing police protection from their plants and cutting off their fuel and food supplies. On the plea of our anti-trust laws, the three American *oficinas* were exempt, but their share was only 3 per cent of the total output.

The Germans, however, gave great trouble. Smarting under the highhanded treatment they had received during the war, they refused to join the new Chilean Nitrate Producers' Association and continued brazenly to undersell. The Chilean Government sent a special embassy to Germany to settle their war claims which were finally compromised by the payment of $1,713,250. At the same time, the mailed fist within the velvet glove was shown plainly by the passage of a new export tax law which collected much heavier duties from non-members of the Association. Thus by compromise and compulsion the Germans were brought into line.

Shortly after the Armistice, the United States Department of Agriculture announced that it would provide farmers with sufficient nitrate for the 1919 spring planting season at 4½¢, provided they paid the freight from the loading point and settled in cash to designated banks.[21] The Nitrate Committee in New York was winding up its affairs and the War Department was also selling off its surplus stocks. After conference with the War Trade Board and the War Department, the Committee announced, in February, that the 226,000 tons of sodium nitrate held in the United States would be sold to farmers and fertilizer makers through the importers, and that the 120,000 tons owned in Chile had been disposed of to foreign buyers.[22] A month later 150,000 tons were released by the War Department to the Department of Agriculture for distribution to farmers according to the plan previously announced.[23] These surplus stocks were gobbled up by American farmers who had been short of nitrogen fertilizers for the past three years and who had war profits to invest in soil fertility. Early in 1920 nitrate prices began to advance again. The Nitrate Producers' Association was effective in controlling production and in London a syndicate of international speculators, known as the Nitrate Pool, established a working corner which was able to run up the prices. But the sharp postwar depression, affecting most seriously commodity prices, had set in. Consumers balked, leaving over a million tons here and in Europe frozen in the hands of importers. At the same time a surplus of over two million tons had accumulated in Chilean ports.[24] Late in June, the Chilean Nitrate Producers' Association announced through its American representative, William S. Myers,[*] that it would offer 100,000 tons monthly to June 30, 1921, the prices to be advanced gradually from 15 shillings 6 pence to 17 shillings, delivery f.a.s. Chile. At the same time the trade was informed that the Association would continue its agreement among nitrate producers until June 30, 1921.[25]

While these prices were maintained rigidly for a while, demand had vanished. Chilean producers, who had been working overtime, began one by one to close down their operations. By the end of the 1921 fertilizer season, four-fifths of the *oficinas* were shut and tens of thousands of men had been thrown out of work. Chilean exchange dropped alarmingly and again a financial crisis threatened. The Association stood firm and these conditions continued up until June 1922, when the price was cut in half. World conditions now improved and during the year ending June 1923, over a million tons were moved out of Chile. But, in the meantime, synthetic production in all countries had been increasing and thereafter the Chileans definitely lost control of the nitrate market.

References

1. Zanetti, *Significance of Nitrogen*, p. 53.
2. *O.P.D. Reptr.* 17 (May 7, 1917).
3. Clarkson, *Industrial America in World War*, p. 393.
4. *Ibid.* p. 391.
5. *Ibid.* p. 264.
6. D. F. Irwin, *Eng. Min. J. 107*, 265 (1919).
7. *Ibid. 105*, 258 (1918).
8. Baruch, *American Industry in War*, p. 167.
9. *Ibid.*
10. Clarkson, *op. cit.* p. 392.
11. *O.P.D. Reptr.* 28 (Apr. 22, 1918).
12. War Ind. Bd., *Price Bull. No. 45*, 5.
13. Zanetti, *op. cit.* p. 56.
14. *Chile 1*, 205 (1926).
15. M. R. Lamb, *Eng. Min. J. 99*, 811 (1915).
16. *Min. Ind. 1918*, 647; Irwin, *op. cit.*
17. L. F. Noble, G. R. Mansfield, *et al.*, Geol. Surv., *Bull. No. 724* (1922).
18. *O.P.D. Reptr.* 79 (Aug. 14, 1916).
19. Baruch, Hearings Subcomm. No. 5 (Ordnance), Select Comm. Expend. War Dept. (House 66:1-3), Feb. 27, 1920, p. 3014.
20. Fed. Trade Comm., *Report on Fertilizer Industry*, 1923, p. 20; Cottrell, *Manufacture of Nitric Acid and Nitrates*, p. 21.
21. *Drug Chem. Mkts.* 4 (Jan. 1, 1919); *O.P.D. Reptr.* 27 (Jan. 6, 1919).
22. *Drug Chem. Mkts.* 11 (Feb. 26, 1919).
23. *Ibid.* 17 (Mar. 19, 1919).
24. Fed. Trade Comm., *op. cit.* p. 21.
25. *Drug Chem. Mkts. 6*, 1157 (1920).

---

[*] Myers had represented the Chilean producers in this country since 1901, when he initiated their advertising and educational campaign. A graduate of Rutgers, he had worked in England under Sir William Ramsay. Returning to the N. J. Agr. Exp. Sta. as chem., he became, in 1893, prof. chem. at Rutgers. As an untiring protagonist for nitrates, he did much to promote the greater use of fertilizers and was a pioneer in cooperative fertilizer experiments in experiment stations. He retired in 1926, died in Jan. 1945.

Chapter 8

NITROGEN FROM THE AIR

BRADLEY AND LOVEJOY PIONEER ARC PROCESS IN AMERICA—CYANAMIDE PLANT BUILT AT NIAGARA FALLS BY AMERICAN CYANAMID—LANDIS ADAPTS AMMONIA OXIDATION TO NITRIC ACID—BUCHER CYANIDE PROCESS BACKED BY ARNOLD—GENERAL CHEMICAL STUDIES HABER PROCESS.

OVER a century before Crookes' grim forecast of starvation for lack of fertilizer nitrate, another Englishman, the misanthropic millionaire-chemist, Henry Cavendish, had identified as nitric acid the compound formed when an electric spark is discharged in the air. This is the basic principle behind the arc process of nitrogen fixation, which consists essentially in passing hot air through an electric arc and cooling it quickly to inhibit the decomposition of the nitric oxide which is formed.

During the intervening years, a number of abortive attempts were made to turn Cavendish's laboratory observation into plant process.[1] In 1899, an aggressive firm of English cotton bleachers, MacDougal & Howles, scored a near-success.[2] For years they had been making considerable nitric acid in their Manchester plant. Disgusted with the delays in shipping nitrates from Chile, disturbed by rising prices, and distrustful of the monopoly, they were prodded into what was a sort of preliminary tryout of the arc process. In attempting to reach and maintain the temperature of 2,000° C. required for the reaction, their new ovens and apparatus were destroyed, and they forthwith abandoned such risky experiments.

Just about this time, two American employees of the Ampere Electrochemical Company, the engineer, C. S. Bradley, and the chemist, Robert Lovejoy, undertook work that led straight to the first successful plant-scale operation of the arc process. The Ampere Company was an experimental corporation formed to discover and develop new electrochemical processes to the point of commercial exploitation. Its organizers were Prof. F. B. Crocker, president, C. A. Doremus, vice-president, S. S. Wheeler, treasurer, C. S. Bradley, A. H. Buch, H. E. Knight, R. D. Lovejoy, Charles B. Jacobs, and N. Thurlow. Originally located at Ampere, New Jersey, it moved to Niagara Falls in 1898.*

---

* It developed a number of successful processes, e.g., method of fusing bauxite to form corundum, sold to and operated by the Norton Emery Wheel Co.; treating barite

JOHN E. BUCHER

C. S. BRADLEY

FREDERICK W. DE JAHN

EDWARD E. ARNOLD

In 1902 the apparatus and patents[3] of Bradley and Lovejoy were acquired by the Atmospheric Products Company. This recently organized, million-dollar corporation built a large plant at Niagara Falls. The operation was not a financial success and it was discontinued in 1904, but the first commercial fixation of nitrogen was indubitably and distinctively American in its origin.* Its inventors were American chemists. It was financed with American dollars. It operated on American soil. This pioneering process achieved remarkable electrical efficiency–948 pounds of 100% acid per kilowatt-year–and it failed economically because the design of its apparatus was impractical for large-scale operation.[4] Furthermore, Bradley and Lovejoy made the significant discovery that the efficiency of the process is greatly increased if the arcs are spread.

To accomplish this improvement Birkeland and Eyde in Norway took advantage of the well-known electrical phenomenon that an arc is deflected by a magnetic field at right angles to it and found that furnaces employing this effect could be built so rugged and so big that large-scale operations were possible. With power at the very low rate of six to seven dollars per horsepower-year, the Birkeland-Eyde process proved a commercial success.[5]

The original Birkeland-Eyde furnace was installed at Notodden, Norway, in 1903. Three years later, three 500-kilowatt furnaces were in constant service,[6] and by 1909 the installation had grown to thirty-five 1,600-kilowatt furnaces. That year the first Schoenherr-Hessberger furnace, invented in Germany in 1905,† was erected at Notodden, in a new plant that was expected to be completed in 1910 at a cost of $15,000,000. The two types of furnace were to be run in parallel comparison to determine which was better.[7]

Even before the first turbine turned in this Norwegian plant, rumors of a practical arc process drifted across the ocean and caught the alert attention of an engineer who for several years had been an indefatigable promoter of hydroelectric enterprises in the Southeastern states. Frank

---

to form barium hydroxide, sold to and operated by the United Barium Co.; synthetic-ammonia process operated by the Atmospheric Products Co.; camphor from turpentine (discovered by Thurlow) and operated at Port Chester, N. Y. [See J. W. Richards, *Electrochem. Ind. 1,* 17 (1902).]

* "I would prefer 'large scale' rather than 'commercial' because actually the Bradley-Lovejoy process failed as a commercial undertaking. The reason for that failure was inability to maintain a proper degree of electrical resistance in the several parts of the apparatus. The place was surrounded with nitric acid vapor which was giving trouble with the principal insulators on the rotary equipment, and more particularly in the large number of choke coils necessary to control the multitude of arcs. Otherwise I think this is a proper honor which should be paid to these pioneers. They certainly got higher yields per unit of electric energy than has been accomplished ever since." (Walter S. Landis, to author, Oct. 20, 1942.)

† Ger. Pat. 201,279.

S. Washburn[8] had already developed a powersite on the Coosa River, the foundation of the Alabama Power Company, and he was planning a more ambitious project at the Muscle Shoals of the Tennessee River. It was quite plain that this larger project would require an industrial consumer of a great block of electric power for its successful operation, and Frank Washburn had been admirablv fitted by a lucky coincidence to sense immediately the importance of the arc process to this projected enterprise. As a young man, he had gone to Chile for the Grace interests to overhaul the engineering aspects of their operations. Quite recently, he had not only surveyed personally all likely powersites in the southern Appalachian Mountains, but had also studied at first hand the industrial and agricultural opportunities of the entire region. Therefore, the sequence of nitrogen from the air to nitrate for fertilizers appealed to him instantly. He sailed immediately for Europe, determined, if this new arc process survived searching investigation, to transplant it to one of his Southern power developments.

The Norwegians welcomed this enthusiastic engineer who so obviously knew the hydroelectrical business. They went even further than courtesy demanded. After showing him every detail of this process and the know-how of its operation, they discussed costs fully and advised him against buying their American rights.[9] Dr. Eyde even confessed that they had had a good man in this country for three years scouting for water-power sites and had found nothing they regarded suitable.[10] This frankness was discouraging, but Washburn was so convinced that nitrogenous fertilizers would make big power installations in the South economically feasible, that he went over to Germany to investigate the cyanamide process.

Originally developed by Frank and Caro,[11] between 1895-98, to produce cyanides for gold recovery,* this process is based on the combination of nitrogen and calcium carbide ($CaC_2 + N_2 = CaCN_2 + C$) industrially effected by passing nitrogen (from liquid air) through retorts charged with powdered carbide and heated initially to 1,000° C. by means of a carbon rod in the center of the charge. The production of carbide involves quantities of coke and limestone—abundant in the southern Appalachians—besides electrical power, and since calcium

---

* The cyanide process was introduced by the MacArthur-Forrest Research Syndicate in 1893. Making possible more complete gold recovery and the profitable working of lower-grade ores, it was an important contribution to the great growth of the world's gold production. Coming just at the time of the exploitation of the South African mines, it helped to raise the world output from 7,883,000 oz. in 1891-95 to 12,447,000 oz., 1896-1900; 15,607,000 oz., 1901-5; 20,995,000 oz., 1906-10; 22,204,000 oz., 1911-15. [See Kemmerer, *Money*, p. 373; Angell, *Story of Money*, Chap. 6; Houston, *Fundamentals of Money*, p. 103. See also Rose, *Metallurgy of Gold;* J. S. MacArthur, *Min. Sci. Press 112,* 851 (1916).]

cyanamide was being publicized for direct application as a fertilizer material, Washburn's hopes revived. He quickly came to terms for the American rights with the Italian company which controlled the Frank-Caro patents.[12] Washburn returned to the United States so enthusiastic over the prospects of cyanamide that, regardless of his new power projects, he determined to manufacture this new chemical product. He had little difficulty in selling this idea to his associates * in the Alabama Powder Company and the American Cyanamid Company was accordingly incorporated, July 22, 1907, with a capital of $1,000,000.

Power from the Coosa River plant was sold up and there was slim chance that the installation at Muscle Shoals would materialize, so the Cyanamid group turned naturally to Niagara Falls. Here they found that the base load of the American company was taken up producing carbide, carborundum, aluminum, and graphite—the electrochemical development at the Falls was still largely in the future—but that the Ontario Power Company wanted badly to locate a big consumer on the Canadian side for the current generated by its new installation. The two young companies entered into a twenty-five-year contract that was mutually advantageous. Ontario got a steady, heavy consumer, Cyanamid bought a big block of cheap power. The contract rate was $10.50 per horsepower-year, much less than what Washburn knew it then cost to make electricity in the South.[13]

With certain modifications in the original Frank-Caro plans, made with the object of improving the product from the viewpoint of fertilizer use, construction of the new plant was pushed and the first carload shipment of cyanamide, 52,240 pounds, was made on December 4, 1909. The works manager was K. F. Cooper; the plant foremen, S. W. Mays and P. J. Ronan.† The initial capacity was 5,000 tons of nitrogen per year. Almost from the beginning expansions were planned, so that in 1910 this output was stepped up to 12,000 tons of cyanamide, and in 1913 the plant was enlarged to a capacity of 32,000 tons. The year the war broke out in Europe, the capacity was again doubled, and actual shipments from the plant totaled 38,000 tons of calcium cyanamide.[14]

At that time one other American nitrogen-fixation plant was in hit-

---

* These included his wife's nephew, W. R. Cole; William H. Lindsey, his partner; A. H. Robinson, a leading Nashville banker; and Charles H. Baker of New York. [See Haynes, *Chemical Pioneers*, p. 252; *Fortune* 66-71 (Sept. 1940).]

† The first two had been associated with Washburn as staff members in his consulting engineering business. Ronan had been with Roessler & Hasslacher at its Niagara Falls plant. Cooper eventually became vice-pres. of the Company and played a big part in the building of the Government cyanamide plant at Muscle Shoals during the war. Mays was later general purchasing agent and Ronan, mgr. of the Company's plant at Azusa, Calif.

and-miss operation. It, too, had been inspired by a Southern hydroelectric enthusiast, James B. Duke,[15] the tobacco man, whose interest in power grew out of his optimistic faith in the development of the South's natural resources. Naturally he appreciated the fertilizer situation and he realized, as did Washburn, the need of large, industrial consumers of power to support Southern hydroelectric enterprises. This led him to purchase the American rights to the Pauling arc process of producing nitric acid, invented by two Austrian brothers, H. and G. Pauling. Their first commercial unit had been built at Innsbruck in the Tyrol. The original pilot-plant unit had been put in operation during 1906 at Gelsenkirchen, Germany, and the plant at Innsbruck went into operation in 1909. At the time Duke purchased the rights, the plant at Innsbruck was using twenty-four furnaces, with a total power consumption of 15,000 horsepower, and the second plant was under construction in southern France.[16] Having control of the Pauling process, Duke financially backed the Southern Electrochemical Company—subsidiary of his Southern Power Company—which built a plant at Nitrolee, South Carolina, to produce nitric acid and ammonium nitrate.[17]

This operation was planned to take up seasonal power, that is, the excess secondary power generated during the six or eight months of high water. It contained four furnaces, an acid-concentration unit, and equipment for conversion to ammonium nitrate, the last using ammonia liquor from the local gas plants. The arc process, unfortunately for these plans, could not produce nitrogen sufficiently cheap to compete with the call for power from the growing Southern textile mills. Moreover, there was little local demand for nitric acid, so Duke, always thinking of Southern resources, tried acidulating phosphate rock with nitric acid to make a new type of superphosphate. Largely because of its mechanical condition—it caked into veritable brickbats—and the stolid resistance of farmers to plant-food innovations, this bold attempt failed. In 1915, high war prices for nitric acid and the prospect of lowering costs by large-scale operations suggested that the plant be enlarged, consequently the capacity was increased to utilize some 7,000 horsepower. Costs, however, were too high * and difficulties were encountered with shipping. In the end, production was concentrated on ammonium nitrate till, in 1916, ammonia became unavailable and the Nitrolee plant closed for the last time.

Prior to our entering the war, abnormal demands of the Entente for nitrogen and its derivatives promoted a number of privately supported projects in this country. In the early part of the year 1914, British

---

* With power charged at the low rate of $10 per hp-yr. the manufacturing costs (exclusive of financial charges) were said to be $90 per ton of 100% acid, power requirements alone being over 3½ hp-yr. per ton. [See *Met. Chem. Eng. 10,* 26 (1912).]

military and chemical leaders, watching the development of the Haber ammonia process and anticipating that sooner or later a European war was inevitable, began exploring the possibilities of a large fixation plant and associated with it a large ammonia-oxidation unit, somewhere on the North American continent. Since the cyanamide process had been operated here for four years and its power consumption was about a fifth as much as the arc process, it was logical to approach the American Cyanamid Company. The project was approved, provided some assurances could be had that ammonia could be converted commercially to nitric acid. It was known that the Germans had been oxidizing ammonia in a small plant at Bochum in the Ruhr; that a second plant was operating in a suburb of Antwerp in Belgium; that several other German chemical groups were hard at work on this ammonia-conversion problem. Special equipment of a type never made in the United States would be needed and this was ordered in Germany for delivery the end of July. Accordingly, Dr. Walter S. Landis,* chief technologist of the American Cyanamid Company, sailed for Europe on the first steamer that left after war was declared. Having done postgraduate work at Heidelberg and being exceedingly well-informed on European nitrogen developments, Landis went straight to some of his good friends among the German technical experts and secured a couple of special autoclaves designed for the conversion of cyanamide to ammonia.† He smuggled these out of Germany just before the authorities clamped down and commandeered all chemical apparatus.

Upon his triumphant return with this valuable equipment, Landis set up a small experimental plant and worked out a method of oxidizing ammonia to nitric acid.[18] Two small plants employing this method were designed, built, and operated by American Cyanamid people under Landis' personal supervision, in connection with du Pont explosives plants. A third, much larger one, was erected at Warners, New Jersey, at the plant of the Amalgamated Phosphate Company, which later became the Ammo-Phos Corporation, subsidiary of American Cyanamid. These operations were undertaken under similar contracts which provided that the American Cyanamid Company would supply the neces-

---

* "My problem was to inspect and accept this equipment and see what could be learned as to progress in the art of converting ammonia to nitric acid. Advent of the war earlier than expected, completely disrupted our plans, but I was unable to bring out some of the autoclaves used to convert cyanamide to ammonia, with the auxiliary equipment and the drawings of the plant. At that time Germany had already made active plans for an enormous expansion of cyanamide production, which by the end of 1915 reached a total of about 400,000 tons, or about 15 times the prewar production." (Walter S. Landis, to author, Oct. 20, 1942.)

† This process, which consists of treating cyanamide with water and steam under pressure, was patented by A. Frank in Germany in 1900 (Ger. Pat. 134,289), and in this country, four years later (U. S. Pat. 776,314).

sary cyanamide.[19] The du Pont installations produced ammonium nitrate, much of which was shipped to France.[20]

The second plant grew out of the chance meeting of Washburn and Duke in London. Both were interested in high-test fertilizer materials. As early as 1910, American Cyanamid had experimented with ammonium phosphate on which it held many patents. While trying to make this same fertilizer at Nitrolee, Duke and the Virginia-Carolina Chemical Company, in which he was interested, had purchased a phosphate mine in Florida. Duke suggested to Washburn that this phosphate rock, plus ammonia from the cyanamide process, was a reasonable basis for a joint operation to produce ammonium phosphate for fertilizer use. With this objective, Warners was chosen as a location halfway between the cyanamide installation at Niagara Falls and the mine in Florida, and the Ammo-Phos plant built.[21] Before it was completed, however, war demands for ammonia had become so great that for the duration of hostilities the output, which eventually reached 30 tons of ammonia gas daily, was marketed as aqua ammonia to munitions makers. In July 1916, the first American commercial installation for the catalytic oxidation of ammonia to nitric acid was erected here.[22] It consisted of two elements of six catalytic units, each of which supplied the nitric acid requirements of sulfuric acid chambers with a capacity of 60,000 tons. This operation continued during the war and shortly after it was installed, Cyanamid discarded its experimental ammonia-oxidation plant at Niagara Falls, Ontario.

While these pioneering efforts to produce ammonia and nitric acid from cyanamide were culminating, Dr. John E. Bucher * had been quietly experimenting with a nitrogen-fixation process starting with cyanide. He had been encouraged in his experiment by Edward E. Arnold, head of the old firm of Arnold, Hoffman & Company, chemical importers and merchants of Providence, Rhode Island. Bucher's process [23] attracted no interest until he read a paper [24] describing his work, at the 9th annual meeting of the American Institute of Chemical Engineers, in June 1917. Instantly this commanded attention because Bucher proposed to fix nitrogen without the use of electrical power.[25] He proposed to briquet an intimate mixture of finely divided soda ash, coke, and iron, and feed the dried briquets into an externally heated, vertical retort where the charge would react with nitrogen at about 1,000° C. to form sodium cyanide. Arnold, whose firm had been appointed New England sales agents for the recently formed Mathieson Alkali Works,[26] organized the Nitrogen Products Company to exploit

---

* Bucher, prof. chem. at Brown, had been trained at Lehigh and Johns Hopkins, and in 1917 became chief chem. of the Pennan-Littlehales Chemical Co., later heading the Research Inst. Ind. Processes at Fort Lee, N. J.

Niagara Falls Plant of the American Cyanamid Co., 1910-14.

the Bucher process.[27] Semicommercial units were set up at Greene, Rhode Island, and at the new Mathieson plant at Saltville, Virginia.[28]

About a year before, December 1916, the American Cyanamid Company had erected a plant at Niagara Falls for making crude cyanide by fusing calcium cyanamide with salt. Pure sodium cyanide was being manufactured at that time by the Roessler & Hasslacher Chemical Company at Perth Amboy, New Jersey, by the Castner-Roessler process, using sodium, ammonia, and carbon. The rights to this process were controlled by the Deutsche Gold-und Silber Scheideanstalt. Upon a cost basis, ammonia from cyanide showed no advantage over ammonia from cyanamide, and the Bucher process never became commercially important, though, as we shall see, a government plant was built in 1918 to produce cyanide for combat gases.[29]

In the efforts of various individuals and corporations to establish nitrogen fixation in this country, the arc process was by no means neglected. Most ambitious of these projects was that of the E. I. du Pont de Nemours & Company which, as early as 1915, began to investigate the Birkeland-Eyde process. It acquired the American rights, and recognizing that the heavy power requirements of this operation demanded for successful operation large quantities of low-cost power, proposed that if the Government granted free water-power rights at a suitable site, it would invest $20,000,000 in an arc-process development, with units for the production of nitric acid.[30] A measure authorizing such a contract was introduced, but Congress at this time was so generally opposed to the private development of powersites that this bill was never brought out of committee.[31]

The first successful operation of the arc process in this country came fifteen years after the premature Bradley-Lovejoy venture, and from an unexpected quarter. During 1916-17, a group of young Norwegians in Seattle, Washington, became interested in applying the neighboring water-power facilities and large limestone deposits to an arc process perfected by F. H. A. Wielgolaski.[32] These men, associated with the Graff Construction Company and the Norway-Pacific Constructions & Drydock Company, raised the initial capital of $750,000 and incorporated the American Nitrogen Products Company. The president and general manager was C. J. Graff, and E. L. Blain was secretary-treasurer.* Using only apparatus and equipment that had been proved out in actual operation in Norway, an experimental unit was built at La Grande, Oregon, and a small production was achieved early in 1917. The capital was now increased to $1,125,000 and the rights to a large waterfall in Snohomish County, northwest of Seattle, secured from the Federal Government. This, it was estimated, would develop some

---

* The other directors were Dr. Ivar Janson, O. A. Lee, and C. Nasten.

230,000 horsepower. Production was in full swing early in 1918. Production of sodium nitrite the previous year had exceeded 1,000 tons, which was marketed through Marden, Orth & Hastings of New York City, selling agents. Again the American Nitrogen Products Company determined to expand in order to develop all of the available horsepower and by greater production to effect operating economies. The sudden end of the war checked this expansion program, but the Company continued to operate successfully.[33]

On September 11, 1912, in the auditorium of the Horace Mann School, New York City, a distinguished German chemist read an impressive paper to the delegates of the 8th International Congress of Applied Chemistry. He spoke slowly in excellent English. Not a word was lost and yet the alert experts who listened to him so attentively could not believe what they heard.

The direct combination of nitrogen and hydrogen to form ammonia can now be accomplished on a commercial scale, said Dr. H. A. Bernthsen, and his listeners were inclined to accept this statement. Certainly the reaction, $N_2 + 3H_2 = 2NH_3$, was demonstrably possible and it was known that a number of the top chemists of the Badische Company, the great Fritz Haber, von Ordt, and Bernthsen, himself, had busied themselves with ammonia synthesis for the past five or six years. But when he began describing the process by which the reaction combining these two stubborn gases was induced, his audience was frankly incredulous. He spoke of a pressure of 200 atmospheres and a temperature of 555° C. (1,022° F.).[34] Such figures were simply beyond the realm of chemical engineer or apparatus builder.

Nevertheless, Dr. Bernthsen was quite correct when he said, "The walls for the first factory for synthetic ammonia are already rising at Oppau near Ludwigshafen on the Rhine." The stupendous engineering difficulties had actually been conquered, largely by Carl Bosch who followed through Walther Nernst's earliest investigations of high temperatures and pressures. This paper was in reality the first report to the world of what was soon to prove to be the most important method of nitrogen fixation, the Haber-Bosch process.

While in this country, Dr. Bernthsen endeavored to interest several American producers of anhydrous ammonia in this process. Although ammonia was just then opening up a promising refrigeration market, he met with but little encouragement. It was generally agreed that the operating conditions were utterly abnormal and that apparatus to handle them safely and efficiently was impractical.[35]

The Badische Company had effectively bulwarked this discovery with strong, broad patents [36] which detailed meticulously the apparatus, temperatures, and pressures, but cleverly avoided particulars as to the catalysts employed or their preparation.[37] This last information was the core of the process so far as its practical operation was concerned. This typical German chicanery was aired by the Alien Property Custodian who, when he took over the German patents in 1917, discovered that of the 5,000 United States patents issued to German chemical companies, nearly 250 covered some aspect of nitrogen fixation and that most of these were not taken out until 1916.[38] Despite the pains taken to keep these secrets, various modifications of the Haber synthesis soon began to appear in several countries.

German methods involved the production of hydrogen from water gas and the introduction of nitrogen as air or as pure producer gas. For satisfactory synthesis the gases must be highly purified, and this costly, tricky step was avoided by using hydrogen from the electrolytic decomposition of water and nitrogen made by the liquid-air process. Furthermore, it was found possible to effect the reaction within a wide range of time, temperature, and pressures, and to use a number of different catalysts. Accordingly, the Haber process may be varied, depending upon these operating factors and the method of preparing and purifying the hydrogen-nitrogen gas mixture.

After it became known here that the Badische plant at Oppau was actually in successful operation by April 1913,[39] Dr. William H. Nichols, remembering, no doubt, the General Chemical Company's experience with the Badische contact-sulfuric acid development, decided to work on an American noninterfering method of ammonia synthesis. It was not till 1918, however, that the de Jahn process was patented, and several years after the war before the General Chemical Company had it in operation.[40]

While the General Chemical Company was beginning these experiments, the Bureau of Soils of the Department of Agriculture, which had been investigating all nitrogen-fixation processes since 1913, came to the conclusion that Haber's was best under American conditions. Accordingly, during the summer of 1916, it began a Haber test unit at the Arlington Experimental Farm, Virginia.[41] This was completed in August 1917, and continued to make experimental runs until January 1918, when it was turned over to the Nitrate Division of the War Department.

In 1914, when Germany declared war, nitrogen fixation from the cyanamide, the arc, and the Haber processes was already producing a total of 80,631 tons of nitrogen. By 1917, when we entered the conflict, the world output had grown to 378,694 net tons.* Our domestic

* *1914:* from cyanamide, 44,035 tons; arc, 23,000; Haber, 13,596. *1917:* from cyanamide, 232,394 tons; arc, 33,000; Haber, 113,300. [See Nitrate Div. (Ordnance), *Report on Fixation and Utilization of Nitrogen,* 1922, p. 5.] For cyanamide imports, see Appendix XVI.

output of fixed atmospheric nitrogen had grown during the same period to the insignificant trifle of 300 tons (omitting the American Cyanamid Company's production in Canada), and as supplies of natural nitrate from Chile were uncertain and insufficient for wartime needs, the Government, as a measure of national security, was forced to step in to aid and expand the nitrogen-fixation industry.

References

1. *J. Chem. Soc. 71,* 181 (1897).
2. *Mem. Proc. Manchester Lit. Phil. Soc.,* Sec. iv, 44 (1900); E. K. Scott, Hearings Agr. & Forestry Comm. on S. 3390, Apr. 1920.
3. U. S. Pats. 709,867 and 709,868 (1902).
4. F. A. Ernst, *Trans. Am. Electrochem. Soc. 51,* 183 (1927).
5. *Met. Chem. Eng. 17,* 145 (1917).
6. S. Eyde, *Electrochem. Met. Ind.* 7, 304 (1909); orig., *J. Soc. Arts 57,* 568 (1909).
7. Schoenherr and Hessberger, *Electrochem. Met. Ind.* 7, 245 (1909); W. S. Landis, to author, Oct. 20, 1942.
8. Haynes, *Chemical Pioneers,* pp. 243-58.
9. F. S. Washburn, Hearings on S. 3390, *op. cit.* pp. 105-238, 413-54.
10. Washburn, Hearings Agr. & Forestry Comm. on S. 4971, Mar. 1916, p. 12.
11. G. Erlwein, *Z. angew. Chem.* 27, 533 (1903); A. James, *Eng. Min. J. 113,* 9 (1922); A. W. Allen, *ibid. 124,* 371, 528, 569 (1927).
12. Landis, Hearings on S. 3390, *op. cit.* pp. 285-320.
13. Washburn, Hearings on S. 4971, *op. cit.* p. 45.
14. Waeser, *Atmospheric Nitrogen Industry,* I, p. 266; *O.P.D. Reptr.* 10 (Dec. 8, 1913); E. J. Pranke, *J. Ind. Eng. Chem. 6,* 415 (1914).
15. Winkler, *Tobacco Tycoon.*
16. Landis, to author, *op. cit.*
17. *Met. Chem. Eng. 10,* 126 (1912).
18. Waeser, *op. cit.* p. 267. For processes, see Landis, *Met. Chem. Eng. 14,* 87 (1916).
19. Washburn, Hearings on S. 3390, *op. cit.*
20. Landis, *ibid.*
21. *Met. Chem. Eng. 16,* 238 (1917); *Fortune* 66 (Mar. 1940); *Drug Chem. Mkts.* 8 (Dec. 20, 1916).
22. H. J. M. Creighton, *J. Frank. Inst. 187,* 712 (1919).
23. U. S. Pat. 1,091,425 (1914).
24. *Trans. 9,* 335 (1917).
25. *Drug Chem. Mkts.* 4 (Mar. 28, 1917).
26. *Met. Chem. Eng. 17,* 252 (1917).
27. J. E. Bucher, *J. Ind. Eng. Chem. 9,* 233 (1917); *Drug. Chem. Mkts.* 15 (Aug. 1, 1917).
28. Curtis, *Fixed Nitrogen,* p. 89.
29. Bur. Mines, *Bull. No. 178,* 58 (1919).
30. *Met. Chem. Eng. 14,* 362 (1916).
31. *Drug Chem. Mkts.* 9 (Dec. 12, 1917); Waeser, *op. cit.* p. 265.
32. Norweg. Pat. 24,195 (1912); Ger. Pats. 258,052 (1913), 270,758 (1914).
33. Waeser, *op. cit.* p. 265.
34. *Met. Chem. Eng. 10,* 637 (1912), *11,* 173 (1913); tr. of paper, *J. Ind. Eng. Chem. 4,* 760 (1912) and *O.P.D. Reptr.* 32B (Sept. 23, 1912).
35. R. J. Quinn, *Drug Chem. Mkts. 17,* 1595 (1925).
36. Haber, Ger. Pats. 229,126, 238,430 (1909); Haber and Le Rossignol, U. S. Pats. 971,501 (1909), 999,025 (1911), 1,006,206 (1911), 1,202,995 (1916); Badische Anilin und Soda Fabrik, Ger. Pats. 235,421 (1908), 259,996 (1911).
37. J. W. Joyes, Hearings on S. 3390, *op. cit.* pp. 45-61, 325-47.
38. Zanetti, *Significance of Nitrogen,* p. 57.
39. *Met. Chem. Eng. 11,* 211 (1913).
40. *O.P.D. Reptr.* 21 (Dec. 30, 1929).
41. *Ibid.* 16 (June 16, 1917); *Drug. Chem. Mkts.* 14 (June 20, 1917).

Chapter 9

THE GOVERNMENT NITROGEN PROGRAM

U. S. SUBSIDY OF NITROGEN FIXATION ADVOCATED AS DEFENSE MEASURE—THREE GOVERNMENT AGENCIES STUDY PROBLEM AND NITRATE SUPPLY COMMISSION MAPS PROGRAM—GENERAL CHEMICAL CONTRACTS TO BUILD SYNTHETIC AMMONIA PLANT—CYANAMIDE PROCESS TARDILY ADOPTED—BUCHER PROCESS AT SALTVILLE.

OFFICIAL INTEREST in the nitrogen problem was sparked in 1903 by General William Crozier. An early, enthusiastic advocate of national preparedness and Chief of Ordnance of the Army, he foresaw the danger of our dependence upon Chilean nitrate. He appraised, quickly and correctly, the military significance of the Birkeland-Eyde arc process. So far as getting definite action, however, his was a voice crying in the wilderness. A few professionals—chemists and artillery officers—recognized that nitrogen from domestic sources was vital to our defense program, but upon a people indifferent to any defense plans the General's warnings were wasted. The average citizen did not know what Crozier was talking about and cared less.

At this time Congress was feverishly interested in hydroelectric developments, especially in the Southeastern states. But this interest was badly biased. It appreciated nicely the political implications of powersites. It was quite indifferent to the economic, military, and agricultural relationships existing between electrical power, nitrogen fixation, and explosives.

Later, by substituting fertilizers for explosives in that sequence, a very lively political interest was whipped up in atmospheric nitrogen. In the opening years of the century, however, when water-power questions arose, Congress was concerned only with conserving our God-given natural resources for the benefit of the people. No politician had, as yet, discovered the vote-winning possibilities of cheaper fertilizers as a class appeal to farmers. In the simple political technique of 1912 the heights of farm subsidies were pretty liberal funds voted to the land-grant colleges for their Experiment Stations and free packets of garden seeds to farmers' wives.

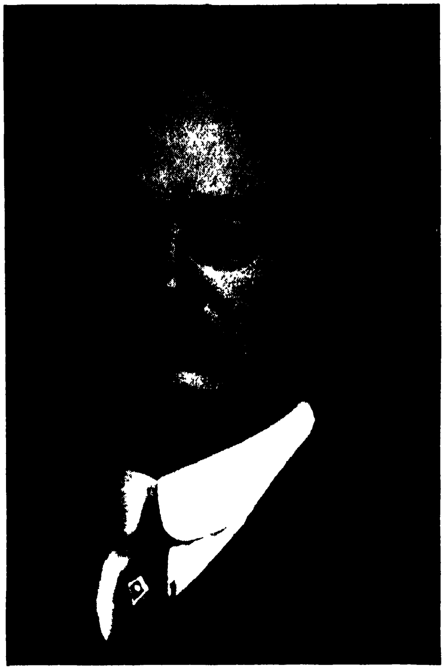
Theodore Roosevelt had not invented the conservation of natural resources, but he had popularized this constructive movement, which he himself summarized: [1]

> The idea that our natural resources were inexhaustible still obtains, and there was as yet no real knowledge of their extent and condition. The relation of the conservation of natural resources to the problems of national welfare and national proficiency had not yet dawned on the public mind. . . . Our magnificent river system, with all its superb possibilities for public usefulness, was dealt with by the National Government, not as a unit, but as a disconnected series of pork-barrel problems, whose only real interest was in their effect on the reelection or defeat of a congressman here and there—a theory which, I regret to say, still obtains.

Out of the welter of water-power legislation introduced into Congress during the decade before World War I, a single powersite rises as significant in the subsequent development of the Government nitrogen program. The Muscle Shoals of the Tennessee River were then generally considered the best potential water power in the entire Southeast. At the same time it was admitted they presented peculiar physical difficulties to quick, economical development. Here the Tennessee drops 150 feet in 30 miles, but at certain points the river sprawls to almost two miles' width. These swift, shallow rapids formed an impassable obstruction to navigation. As far back as 1835, therefore, Alabama built a series of canals through the Shoals, and in 1870, the Federal Government, assuming control of all navigable streams, so improved the Muscle Shoals Canal that it became available for small boats. The river was, nevertheless, still insignificant as a means of water transportation in any sense competitive with the railroad.[2]

When Frank Washburn's personal survey of the Appalachian watershed focused his attention on Muscle Shoals, he realized at once that no power installation plan would be approved that did not maintain the full navigability of the Tennessee. Yet to do so would enormously increase the cost of dams to provide a sufficient head of water for a large, continuous electrical output. His engineers estimated that it would cost so much to maintain the Tennessee as a navigable stream, that the carrying charges at 6 per cent would represent 80 per cent of the cost of power produced at Muscle Shoals. The extraordinary investment required quite offset the favorable aspects of the river; the rich, natural resources of the region; the potential power market in the Birmingham district. Commercial development by private interests was only feasible with the financial cooperation of the Government. Accordingly, he worked out a program whereby the Government would construct a larger canal. The Government and private capital would jointly build the necessary dams. Private interests would erect the power plants and transmission lines.[3]

This joint program had the hearty approval of Alabama and the neighboring states which had everything to gain. Army engineers



CHARLES L. PARSONS

FRANK S. WASHBURN

Industrial & Engineering Chemistry

THEODORE SWANN

HENRY WIGGLESWORTH

sanctioned the plan as providing, at smallest expense to the Government, a maximum improvement in the navigation of the most important river in the Southeast. With this support, the bill introduced by Representative Richardson of Alabama, embodying this proposal of Washburn's from the Muscle Shoals Hydroelectric Power Company, seemed certain of approval. Nevertheless, the bill dragged through several sessions, and when it was finally passed, it was vetoed by President Taft. Following Theodore Roosevelt's lead in conservation, Taft had served notice on Congress that he wanted "not a lot of mill-dam legislation, but one national water-power law." When next Muscle Shoals appeared on the floor of Congress, the war in Europe was raging and the development of any powersite had become associated with the Government nitrogen program.

During 1915, a number of bills providing for a wide variety of nitrogen-fixation proposals were introduced into Congress.[4] Most of them died in committee; none was enacted. Great confusion befuddled the situation, which demanded prompt action; but the experts disagreed at almost every point, and no clean-cut, comprehensive plan came forth that could command the support of everyone.

In the end, after bitter debate and several amendments, the National Defense Act of 1916 was passed. One of its sections was the first definite nitrogen legislation enacted in this country. It provided:

> Section 124. Nitrate supply—The President of the United States is hereby authorized and empowered to make, or cause to be made, such investigation as in his judgment is necessary to determine the best, cheapest, and most available means for the production of nitrates and other products for munitions of war and useful in the manufacture of fertilizers and other useful products of water power or any other power as in his judgment is the best and cheapest to use; . . .
>
> The sum of $20,000,000 is hereby appropriated out of any moneys in the Treasury not otherwise appropriated, available until expended, to enable the President of the United States to carry out the purposes herein provided for.

Passage of this act, which was signed by President Wilson on June 3, 1916, was the starter's gun that sent the claimants off on a wild scramble over various powersites and competing processes. Committee hearings and debates in both Senate and House on this and the various other nitrogen bills had at once emphasized the gravity of the situation and the multiplicity of the conflicting proposals. Particularly educational were the Senate Agriculture & Forestry Committee hearings on the bill (S. 4971) introduced by the same Senator Smith[5] who had approached the War Industries Board for help in securing Chilean nitrate for the farmers. The statements presented[6] were almost a complete symposium on the nitrogen problem and particularly illuminating, since this bill, though indefinitely postponed, became the direct forerunner of the nitrate clause in the National Defense Act.

Among those who testified, Dr. Leo H. Baekeland dramatized the need for nitrogen by declaring that in the battles of Neuve Chapelle and Loos, more explosives had been used in three days than in the whole campaign of the War of 1870.[7] Such huge demands, he pointed out, could not be met by Chilean nitrate, and he advocated a government-built-and-owned nitrate plant which might be used in peacetime for making fertilizers.[8] In the light of subsequent Muscle Shoals developments, it seems curious that the Department of Agriculture opposed the establishment of a government nitrogen-fixation plant and favored the recovery of nitrogen from by-product coke-oven operations.[9]

Dr. Thomas H. Norton recommended the construction of three nitrogen plants throughout the United States: one in the South to manufacture nitrates and some nitric acid; a second in the Northwest to supply nitrates for agriculture and nitric acid for the rapidly expanding industries of that section; the third and largest in the Northeast to meet nine-tenths of the domestic demand for nitric acid. At the same hearings,[10] Dr. Norton declared:

> An American in 1903 presented an application for a patent for a method of fixing nitrogen in the air. That application lay dormant in our Patent Office until August 1915. It took 12 years to decide that the method was patentable. Everybody had forgotten about it. Four or five years after that application was presented, Professor Haber, the German who developed the method of transforming the nitrogen of the air into nitric acid (*sic.,* ammonia), worked out on paper mathematically, and also in his laboratory, the possibility of increasing the yield of ammonia (*sic.,* nitric acid) in the arc process by bringing in the element of pressure. . . . That was the fundamental idea of this patent application of 1903.

Before this Senate committee, Frank Washburn suggested Muscle Shoals, Tennessee, and Priest Rapids on the Columbia River, in Oregon, as the two best possible water-power sites. He estimated that it would cost at least $20,000,000 to build a dam, power plant, and nitric acid plant at Muscle Shoals. He proposed that the Government furnish power to private interests which would agree to make an equal investment in a nitrogen-fixation plant. He suggested that after the war the fixation operation be converted into an ammonium phosphate-fertilizer operation. This was obviously a modification of the joint-development plan he had fathered several years previously.

During the past six months, Washburn had been called into conference with the War Department on ways and means of guaranteeing adequate explosives for our Army, should we be drawn into the war.

The feeling in military circles had been that it would be necessary for the Government to build and hold idle a plant capable of producing 180,000 tons of nitric acid yearly.

"We have considered," Washburn said to the Senate Committee, "a great many different plans, but they have all the same basic principle. Since the original suggestion to which I was most attached, namely, that of having the Government guarantee the bonds and take a mortgage on the property, was early abandoned, they have all turned to the proposition of the Government furnishing power as a power producer and private capital furnishing the rest. The War Department," he concluded, "was favorably disposed to such a plan; the Department of Agriculture, noncommittal." [11]

Synthetic production of nitrogen for explosives required answers to two correlated but distinct questions: Which process of nitrogen fixation? What most advantageous plant location?

If we take up these phases of the problem one by one, it is easier to trace a path through the confused, hurried, and sometimes conflicting efforts to provide nitric acid and nitrate, the end-products sought. In so doing, however, it must not be overlooked that intense activity along several lines proceeded simultaneously and often overlapped. Many agencies were involved: Army and Navy, the Departments of Agriculture and the Interior, numerous companies, big and little, even colleges and universities. There were sharp clashes of conflicting interests both within and without the Government. Forceful individuals now opposed each other, and again worked together. Much time was lost in wrangling over technical details and in bargaining the terms and conditions of contracts. Mistakes were made and the abrupt end of the war robbed these Herculean labors of a final, triumphant achievement. It made them appear but a dubious accomplishment, one of the least satisfactory of the chemical industry's war jobs. Nevertheless, nitrogen from the air had more important after-effects, political, economic, and chemical, than came from the sensationally successful establishment of a synthetic organic chemical industry in the United States.

No definite nitrogen program was adopted until May 1917. It was formulated tardily in the report of the Nitrate Supply Committee, consisting of General Crozier and Admiral Ralph Earle, top ordnance officers of the two branches of the service; General William M. Black, chief engineer of the Army; F. W. Brown, Bureau of Soils; Dr. Baekeland; Gano Dunn; Dr. Charles H. Herty; Dr. William F. Hillebrand, Bureau of Standards; Dr. Arthur A. Noyes; Dr. Charles L. Parsons; and Dr. Willis R. Whitney. This committee was appointed by the Secretary of War to investigate all previous investigations and to reconcile the conflicting conclusions of two earlier reports.

These reports had been made by Dr. Charles L. Parsons,* chief chemist of the Bureau of Mines, and by a committee of technical experts appointed by the National Academy of Sciences and the American Chemical Society.†

Upon the recommendations of Secretary of Interior Lane, the War Department appointed Dr. Parsons chief chemical engineer of the Ordnance Department and sent him with Eysten Berg, an engineer of Norwegian birth long familiar with European nitrogen-fixation developments, abroad in October 1916, to study fixation and nitric acid processes. Their investigations were preliminary to any government plan or subsidy for production in this country.[12] With Berg, Dr. Parsons visited fixation plants in France and Italy and later, alone, investigated those in England, Norway, and Sweden.‡ He returned on Christmas Eve and made a preliminary report to the Ordnance Department on January 17, 1917, and a final report on April 30, 1917. Attached to the latter was a supplementary report by Berg describing the arc, cyanamide, and Haber processes, and setting forth in detail their respective power requirements. Dr. Parsons' report § recommended the adoption of the modified Haber process of the General Chemical Company and the Bucher cyanide process of the Nitrogen Products Company.¶

* Parsons, a Cornell B.S. in 1888, had gone to the New Hampshire Agr. Sta. as chem., later becoming prof. chem. at N. H. Coll., whence he moved to the Bur. Mines in 1911. He was an active figure in wartime nitrogen activities, and since 1907 has served the Am. Chem. Soc. as its sec'y and chief admin. officer. He has been awarded the Nichols and Priestley medals, hon. degrees by Maine and Pittsburgh, and was decorated by the French and Italian Governments.

† Dr. Arthur A. Noyes, of Mass. Inst. Tech., chairman; Dr. Baekeland; Gano Dunn; Dr. Herty, then prof. chem. at N. C.; Dr. Warren E. Lewis; Michael Pupin, Columbia physicist; Prof. Theodore W. Richards; Elihu Thompson; and Dr. Willis R. Whitney. The A.C.S. named Baekeland, Herty, Lewis, and Whitney.

‡ "I have no record of any nitrogen-fixation plants in England at this time." (C. H. MacDowell, to author, Nov. 14, 1942.)

§ In reprint of original in *J. Ind. Eng. Chem.* *9*, 833 (1917), all confidential matter and cost data have been omitted.

¶ "All I recommended was that a small experimental plant be built to try the Bucher process out. . . . As to the modified Haber, my recommendation was simply for a small pilot plant to work out difficulties which I knew would take place. At that time the situation was not so urgent as it later became and we hoped that we had time for experimentation. The plant was made bigger than a normal-sized pilot plant for the reason that we hoped to get it into operation where it could produce. Nevertheless, it was essentially an experimental plant. As you point out, I was from the beginning opposed to the cyanamide process; not because I did not know that it would produce, for I knew perfectly well, as did everyone else, that it was the only process that would produce. It was solely a question of cost, and at that time we were supposed to take this factor very seriously into consideration. Later on, as you state in Chapter 10, the conclusion was reached that 'in the urgent emergency, cost was no object and the cyanamide process offered the quickest, surest means of nitrogen fixation available.' I joined heartily in the conclusion that we must proceed, irrespective of cost and qual-

The report * of the committee appointed by the National Academy of Sciences, on the other hand, advocated any fixation process proved out in the pilot plant, in view of the urgency of the needs. It also recommended that the Government finance, at suitable locations, as much hydroelectric power as possible and sell this power at cost to private companies for use in fixing atmospheric nitrogen. It thus intimated indirectly its belief in the cyanamide process and its approval of Washburn's proposals of cooperation by government with industry. The consensus of opinion among those who were most familiar with the nitrogen problem—legislators, Army and Navy officers, other government experts, economists, engineers, and chemists—favored this form of subsidy as simplest and most economical.

The conclusions of these reports were so divergent that the Nitrate Supply Committee was asked to reconcile them and lay down the pattern for an official nitrogen program which it did as follows:

I. That the Government negotiate with the General Chemical Company for the right to use its synthetic-ammonia processes.

II. That contingent upon satisfactory result of such negotiations, there be set aside from the $20,000,000 appropriated, such sum, estimated at about $3,000,000, as should be necessary to build a plant to produce by that process about 60,000 pounds of ammonia per 24-hour day; location southwest Virginia preferably.

III. That out of the same appropriation, $600,000, or as much more as needed, be set aside for building a plant for producing by oxidation of ammonia about the equivalent of 24,000 pounds of 100 per cent nitric acid per 24-hour day.

IV. That the War Department proceed at the earliest practical date with the construction of the oxidation plant, and contingent upon satisfactory arrangements with the General Chemical Company, with the construction of the synthetic-ammonia plant also.

V. That the Government negotiate with the Nitrogen Products Company with the view to a contract for the right to use that company's patents and proceed with experimentation looking toward the industrial development of the Bucher process for production of ammonia through cyanide; and that contingent upon satisfactory arrangements as above a sum not over $200,000 be allotted out of the nitrate supply appropriation.

VI. That out of the $20,000,000 nitrate supply appropriation $100,000 be allotted for active investigation of processes for the industrial production of nitrogen compounds useful in the manufacture of explosives or fertilizers—this under the supervision of the War Department.

VII. That in order to increase the production of ammonia and toluol the

---

ity of process, to build a plant. . . . There is today a remarkable resemblance between this nitrogen problem and its history and the rubber problem which is now before us and its history to date." (C. L. Parsons, to author, Oct. 26, 1942.)

* Preliminary, June 2, 1916; summary, Jan. 6, 1917; final, Jan. 29, 1917.

Government promote the installation of by-product coke ovens by directing priority in production and transportation of materials and parts.

VIII. That the decision as to more extensive installation of nitrogen-fixation processes and water-power development in connection with them be postponed until the plants above recommended are in operation or until further need arises.

IX. That while the preceding recommendations include all the measures that can now judiciously be taken for the fixation of ammonia, it is the opinion of the committee that the immediate accumulation and permanent maintenance of an ample reserve not less than 500,000 tons of Chile saltpeter is the measure most urgently necessary.[13]

Looking backwards, it is hard to comprehend why the Nitrate Supply Committee made no direct provision for any installation of the cyanamide process, the only fixation process which up to that time had been operated successfully on a commercial scale on this side of the Atlantic.[14] A great show was made of the exorbitant power requirements of the cyanamide process, a weighty argument no doubt, but under the circumstances not the determining one. As events subsequently proved, the program set up on the basis of this committee's report was costly both in time and in money.

The President referred these recommendations to an Inter-Department Board—the Secretaries of War, Interior, and Agriculture—which he had named January 15, 1917, to examine the comparative merits of a great number of possible powersites which were being offered the Government for development.[15] During the early months of 1917, the Board visited numerous locations in the South and East and held hearings on the spot; but the scuttling of the cyanamide plans by the Nitrate Supply Committee stopped these investigations. After the Board gave its approval to the Committee's program, all nitrogen efforts were bent upon the General Chemical and Bucher processes. A week after this official go-ahead was received, General Crozier set up a Nitrate Division in the Ordnance Department, with Colonel J. W. Joyes in charge. Throughout the war this remained the active nitrate administrative body.

Dr. William H. Nichols was convinced by pilot-plant experiments at Laurel Hill, Long Island, that the Haber process as modified by de Jahn and the Company staff would work commercially. He therefore proceeded with plans for a million-dollar fixation plant to produce seven and a half tons of ammonia a day, at Shadyside, New York. Blueprints were prepared and materials and apparatus ordered. All were offered to the Government: the process free of royalties; the plans and materials, on hand or ordered, at cost. Some supplies had been ordered as early as November 1916, eight months previous, so that invaluable time was saved. The terms had been already agreed upon, and the contract * was formally executed September 20, although made retroactive and covering assistance by the Company from the date of the instructions of the Secretary of War, July 13, 1917.

This contract covered sufficient materials and apparatus to construct what was to be known as United States Nitrate Plant No. 1, for which the Government paid $500,000 plus 6 per cent interest. The contract gave the Government use of all General Chemical Company processes and designs, patented or otherwise, royalty-free for the production of munitions of war, and a five-dollar royalty for each short ton of fixed nitrogen converted into fertilizer products. Any other use of government-produced nitrogen by this process was specifically forbidden. The staff of 30 chemists and engineers which had developed the process, including de Jahn, was placed at the disposal of the President with the understanding that the Government would pay existing salaries. The Government and the Company mutually agreed to exchange promptly full information, with the right of free use of any modifications or improvements in the process or apparatus which either discovered.[16]

The Nitrate Division had executed this contract, acting under mandatory orders from the Nitrate Supply Committee. There was no time for further engineering study and it was tacitly understood that once the Company's proposal was accepted, the investigation stage was definitely closed. Nevertheless, about the middle of August, Colonel Joyes inspected the experimental plant of the General Chemical Company. He was accompanied by a member of his staff and was guided through the plant by the inventor of the process. So unfavorable an impression was received, that several junior Army officers—chemists and chemical engineers—were at once detailed to the plant to make a thoroughgoing examination and appraisal. Lack of adequate operating records and the uncertainty of getting the necessary high-pressure apparatus raised grave doubts as to the reliance which could be placed in this process to produce nitrogen within the time limit set.[17]

Strident calls to hurry the production of more explosives magnified these fears. It had become quite evident that the requirements for ammonia and nitrate had been seriously underestimated and that a larger, more certain source of nitrogen was urgently necessary. Greater atmospheric nitrogen capacity was obviously the only dependable assurance of meeting the needs.

General Crozier called Frank Washburn to Washington. This was in September 1917. In April 1916, Washburn had written the Ord-

---

* Reprinted on pp. 190-199 of the Graham Committee (House 66:1-3) hearings.

nance Department,* urging them to consider ammonium nitrate as a shell explosive.[18] In view of the shortages of toluene, glycerin, and alcohol; the difficulties of the Allies in supplying their own needs for high explosives; and the prospect of a large American expeditionary force, this seemed a sensible suggestion. The Ordnance Department replied, however, that it would "prefer to have our troops use the powders with which it was familiar." When the Nitrate Supply Committee was studying the nitrate reports referred to it, Washburn, in his own words,[19] "did everything possible to deter the Committee from its campaign of experimentation in the face of the enemy," offering them all the original records, accounts, and technical data of the American Cyanamid Company. His testimony was discounted as being prejudiced by his financial interest in the cyanamide process. Five months later, General Crozier told him frankly, "Unless the Cyanamid Company can and will provide the plants and produce the materials within 12 months, the plans for placing a great fighting force on the battlefields in France for the spring offensive of 1919 cannot be carried out."

October 13, 1917, the American Cyanamid Company presented its first proposal to build the necessary plants to produce cyanamide, ammonia, nitric acid, and ammonium nitrate for cost plus 5 per cent; to sell these products for munitions and fertilizers at cost with no royalty; the plants to become the Company's property at the end of the war. This offer was rejected. For a month proposal and counterproposal were argued until a final compromise, not wholly satisfactory to either party, was effected and a contract[20] signed on November 16, 1917.

Loath to risk its capital assets, the Company proposed to set up a subsidiary, the Air Nitrates Corporation, giving to it every assistance and a license for all its patents for a royalty of 6 mills per pound of nitrogen produced, equivalent to ¼ cent per pound on ammonium nitrate. The Air Nitrates Corporation would build the plants for which it would receive as designing and construction fees 3⅓ per cent of the cost of these plants, estimated at $30,300,000, with a maximum fee set at $1,000,000; plus a ¼ cent per pound manufacturing fee on all ammonium nitrate delivered.[21] The operating fee was to cease June 1, 1921, and the royalty fee thereafter would be determined by arbitration.[22] Later, in June 1918, when the contracts were being drawn for

---

* "I have no doubt that Washburn wrote the Ordnance Dept. about ammonium nitrate, but I had made a full report on it to Gen. Crozier immediately after my return from Europe a number of months before, and advised him to get right into the production of Amatol, a mixture of ammonium nitrate and TNT. He had it under full consideration many weeks, in fact at least two months, before Washburn's letter arrived. I made quite a careful study of it in Europe and was asked by the ordnance people in France to bring back the information to Gen. Crozier. This I did." (C. L. Parsons, to author, Oct. 26, 1942.)

two additional cyanamide plants (U. S. Nitrates Plants Nos. 3 and 4), a specific provision was added for a royalty to be paid, if the Government manufactured in any of these plants after the war.[23]

Lively interest in the Bucher cyanide process was provoked during the summer of 1917 by confidential reports received from British and French Army field laboratories on cyanide compounds in gas warfare. In October, the French High Commission asked our help in providing this chemical for shell loading and Secretary Baker at once accepted the offer of Secretary Lane to lend the Interior Department's services to work up the Bucher experimental plants to commercial operation. Dr. Parsons, who had advocated government aid in developing the Nitrogen Products Company plant at Saltville, was put in charge and $750,000 allotted for the project.[24] A special cyanide committee of the Gas Warfare Service, consisting of Dr. J. F. Norris, Dr. John Johnston, Colonel William McPhearson, and Colonel William Walker[25] recommended doubling this plant and the appropriation was raised to $2,000,000.

Rights to the Bucher process were secured on terms substantially similar to the contract with the General Chemical Company. Location at Saltville, which Parsons had recommended because of the local availability of coal, soda, and waste nitrogen from the carbonating towers of the adjacent Mathieson Alkali plant, was literally forced by the demand of that company, parent of the Nitrogen Products Company, that this site be chosen if its process were to be employed. When this supply of free, waste nitrogen did not materialize in sufficient quantities, the Government was obliged to arrange with the Air Reduction Company for an installation of three Claude process-nitrogen columns. This company, manufacturing liquid air and its by-products, had been experimenting with the cyanide process in its Jersey City plant and eventually evolved a working modification of the Bucher process.[26] The Saltville plant, known as United States Chemical Plant No. 4, was fired on September 4, and after initial difficulties, achieved an output of 2,714 pounds of cyanide during the first week of December 1918, when it was shut down.[27]

During the summer of 1918 the Government nitrogen program, already augmented by the three cyanamide plants (United States Nitrate Plants Nos. 2, 3, and 4), was again revised upwards. Projected capacity still fell short of expected needs for the campaign of 1920. The War Industries Board had raised the requirements of synthetic nitrogen from one-quarter to one-half of all our munitions needs[28] and the Nitrates Commission * advised the immediate establishment of a nitrate experi-

---

* Appointed Mar. 28, 1918, to speed nitrogen production and consisting of Dr. Arthur A. Noyes, chairman, Gen. Charles B. Wheeler, Rear Adm. Ralph Earle, Dr. Charles

mental station to test and bring to semi-plant scale any likely process for the manufacture of any nitrogen products. It also counseled that the plan urged by Baruch and Summers to redouble the cyanamide plant output be held up until the results of General Chemical's synthetic process, the new cyanide processes of the British Government and Air Reduction Company, and the nitride process of the Aluminum Company of America, could be more accurately evaluated. Its report was received August 24th and approved September 3, 1918.

Already communiqués from the Western Front told of stunning Allied attacks under which the enemy was beginning to crack. Therefore, this final phase of the Government nitrogen program never materialized. Even before the signing of the Armistice, all plans for greater nitrogen-fixation capacity had been shelved.

REFERENCES

1. Roosevelt, "Autobiography," *Works*, XXII, p. 448.
2. Hearings Mil. Aff. Comm. (House 69:2) on H.R. 16396 and H.R. 16614, Pt. 3, pp. 1-10.
3. F. S. Washburn, Hearings Agr. & Forestry Comm. on S. 3390, April 3, 1920, pp. 108, 115.
4. H.R. 12368, H.R. 13169, H.R. 13346, H.R. 13719, S. 4971, S. 5069, S. 5316.
5. Sen. Rept. 325, Apr. 4, 1916.
6. Hearings Agr. & Forestry Comm. on S. 4971, Apr. 1916.
7. *Ibid.* p. 109
8. *Weekly Drug Mkts.* 7 (Apr. 26, 1916).
9. *O.P.D. Reptr.* 113 (Sept. 25, 1915).
10. Hearings on S. 4971, *op. cit.* p. 73.
11. *Ibid.* pp. 16, 23, 31, 46, 53.
12. *O.P.D. Reptr.* 19 (Aug. 21, 1916).
13. Nitrate Div. (Ordnance), *Report on Fixation and Utilization of Nitrogen*, 1922, p. 264.
14. D. P. Gaillard, Hearings Subcomm. No. 5 (Ordnance), Select Comm. Expend. War Dept. (House 66:1-3), Sept. 4, 1919, p. 180; *Drug Chem. Mkts.* 7 (Sept. 12, 1917).
15. Nitrate Div., *op. cit.* p. 263.
16. J. W. Joyes and H. Wigglesworth, Hearings Subcomm. No. 5, *op. cit.* Jan. 3 and Feb. 6, 1920.
17. Nitrate Div., *op. cit.* p. 268.
18. *Met. Chem. Eng. 14*, 419 (1916), *18*, 2 (1918), *19*, 1 (1918); Washburn, Hearings on S. 3390, *op. cit.* p. 117.
19. Hearings on S. 3390, *op. cit.* p. 119.
20. Text, *ibid.* pp. 396-410.
21. G. J. Roberts, Hearings on S. 3390, *op. cit.* p. 97.
22. Joyes, Hearings on S. 3390, *op. cit.* p. 326; contract and list of patents, pp. 396-410.
23. Final contracts, Hearings Mil. Aff. Comm. on Muscle Shoals Propositions, Feb. 2, 1922, pp. 135-50.
24. Nitrate Div., *op. cit.* p. 300; Waeser, *Atmospheric Nitrogen Industry*, I, p. 278.
25. V. H. Manning, Bur. Mines, *Bull. No. 178-B*, 58.
26. Nitrate Div., *op. cit.* pp. 149, 165; Curtis, *Fixed Nitrogen*, p. 89.
27. C. O. Brown, *J. Ind. Eng. Chem. 11*, 1010 (1919).
28. Baruch, Hearings Subcomm. No. 5, *op. cit.* Jan. 1, 1920, p. 3017.

L. Parsons, Leland L. Summers, Gano Dunn, Dr. Willis R. Whitney, and Col. Joyes, chief of the Nitrate Div. Col. O. O. Horney, representing the Surveyor Gen. Supplies, and Walter Robbins and Frederick Darlington, the Electrical & Power Equipment and the Power Sections of the War Ind. Bd., attended officially. This commission had approved building of the cyanamide plants.

Chapter 10

THE GOVERNMENT NITROGEN PLANTS

PLANT NO. 1, HABER PROCESS MODIFIED BY GENERAL CHEMICAL, FAILS TO ACHIEVE COMMERCIAL PRODUCTION—PLANT NO. 2, CYANAMIDE PROCESS WORKED OUT BY AMERICAN CYANAMID, ONLY SUCCESSFUL NITRATE OPERATION—OTHER CYANAMIDE PLANTS INCOMPLETE—NAVY'S NITROGEN PROJECTS.

IN EXECUTING its oft-revised nitrogen program, the Government undertook the construction of five different fixation plants. One only—U. S. Nitrate Plant No. 2, the cyanamide process, at Muscle Shoals, Alabama—was in successful commercial operation at the signing of the Armistice. Another, United States Nitrate Plant No. 1, the General Chemical Company's modification of the Haber ammonia synthesis, was completed and operating upon an experimental basis at Muscle Shoals. Three were never finished. The incompleted plants were: United States Nitrate Plant No. 3 (cyanamide process) outside of Toledo, Ohio; United States Nitrate Plant No. 4 (cyanamide process) at Broadwell, near Cincinnati, Ohio; and the Navy Nitrogen-Fixation Plant (modified Haber process) at Indianhead, Maryland.

Although Nitrate Plant No. 1 never operated satisfactorily, it was the first Haber ammonia synthesis attempted outside Germany and it was important as a commercial-scale forerunner of the synthetic-ammonia industry later established in the United States by private companies. The whole project labored under exceptional difficulties.[1]

The high-pressure apparatus required was something quite outside the experience of American metallurgists and equipment makers. Furthermore, but two steel companies in the country—Bethlehem and Midvale—were equipped to build the 12, hollow-forged steel cylinders in the large size needed, and both these firms were swamped with war orders placed earlier by the Army, Navy, and the Emergency Fleet Corporation. Finally, the location, to put it mildly, was inconvenient. It was not close to any large center of population, so that roads, gas and electrical services, housing for workmen, and the labor force, itself, all presented extraordinary problems.

The contract was let October 2, 1917 (retroactive to August 18), to the J. G. White Engineering Corporation of New York. So many imponderables entered into the calculations that considerable time was consumed in attempts to define the work more clearly. Finally a cost-plus 9 per cent engineering and administrative fee was agreed upon as the only practicable basis. Plans and specifications were prepared by the White engineers under the direction of the General Chemical staff.

Nine possible sites had been submitted to the Secretary of War. Four of these—Chattanooga, Knoxville, Sheffield, and Birmingham—were starred as superior locations, with Chattanooga indicated as first choice, but the final selection was to have the approval of President Wilson.* He chose Sheffield and the Government, working through a committee of landowners, secured title to 1,839 acres, some 750 lots being donated and others bought at half their appraised value. The first work party reached Sheffield October 4, 1917, and construction began eight days later.

Original specifications called for a daily capacity of 60,000 pounds ammonia. About 8,000 pounds of this were to be converted into nitric acid. But no plans had been made for the chemical disposition of the resulting 24,000 pounds of nitric acid or the remaining 52,000 pounds of ammonia. The Ordnance Department, having been convinced of the usefulness of ammonium nitrate as an explosive, decided early in 1918 to oxidize half the ammonia and combine this nitric acid with the remaining ammonia to make about 125,000 pounds of ammonium nitrate daily or, as it was expected, 22,000 tons a year. The nitric acid-concentration plant, which was already building, was to be completed as an experimental unit. Work was immediately begun on this revised schedule and a contract made with the Chemical Construction Company, Charlotte, North Carolina, to design and construct a complete nitric acid plant. Plant No. 1 was built according to these plans and blueprints were prepared for smokeless powder, picric acid, and TNT plants to be erected near by. Had all units been completed, 200,000 pounds of 56% ammonium nitrate solution would have been produced daily, then evaporated and grained to the finished product. But all sorts

---

* "If you want the exact truth, the Inter-Department Board was supposed to settle this question, a board consisting of Houston, Lane, and Baker. I was present at their last session; indeed, I voted Lane's wishes. The Board definitely recommended that the plant go to North Chattanooga on an island especially suited for the purpose, back of the mountains, near to coal and sulfuric acid, where water power was unnecessary. This was quite in accord with the opinion of the officers of the Ordnance Department who had viewed the situation. The question was supposedly settled. Two weeks later notice came that the President had ordered it to Muscle Shoals. Being Commander-in-Chief, he had the power, just as Roosevelt has today, and he acted in like manner. Secretary Lane told me personally that 'it was damned politics' and I most heartily agreed with him. It was done to please Bankhead and Underwood of Alabama. . . . You will find it all in the Graham Committee report, including a copy of the report of the Inter-Department Board." (C. L. Parsons, to author, Oct. 26, 1942.)

of operating difficulties arose to forestall the plans as drawn up. They had to be solved one by one.

Nevertheless, construction of the plant was completed in record time. On June 4, 1918, less than four months after the first steel was set, the powerhouse boilers were fired. The oxidation unit produced its first nitrous oxide on July 1. On July 15, the first nitric acid, 50%, was drawn off at the absorption tower and placed in storage. The first synthetic ammonia was produced September 16, and on October 28 nitric acid was neutralized to ammonium nitrate liquor. The day after the signing of the Armistice—November 12—the first ammonium nitrate was produced.

At every stage in the operation revisions, sometimes radical changes, were necessary. Peculiar difficulties developed in the producer-gas purification system, in the hot caustic system for removing carbon dioxide, and especially in the ammonia synthesis and liquefaction units. The catalysts for the carbon monoxide conversion and sodium amide for gas purification gave little chemical trouble, but the catalyst for the ammonia synthesis, the well-hidden secret of the German patents, which was vital to the success of the operation, failed conspicuously.

Therefore, the Nitrate Division established, with the assistance of the Department of Agriculture, an experimental laboratory at Arlington, Virginia, devoted specifically to this problem. This laboratory, according to its director, Dr. Richard C. Tolman,[2] was able to develop a catalyst producing over 16 per cent ammonia, compared with 7 to 8 per cent of the General Chemical Company's catalyst. Moreover, the latter was quickly and permanently destroyed by impure gas, whereas the laboratory's catalyst gave as good as 12 per cent results continuously over long periods of time under ordinary commercial conditions. Later, the Solvay Process Company, affiliated with the General Chemical Company, sought from the Government exclusive use of this catalyst, which consisted of a secret mixture of iron and chromium oxides. This was refused.[3] Up to the signing of the Armistice, however, this troublous problem had not been solved. It was later turned over for further investigation to the Fixed Nitrogen Research Laboratory established at the American University.

The satisfactory catalyst for the conversion of carbon monoxide to dioxide was supplied by the General Chemical Company. This company also erected a special plant to manufacture the sodium amide used in the gas-purification system.

Many of the kinks in this new and difficult synthetic-ammonia operation[4] were later ironed out. Others, sufficiently serious to block successful continuous operation, were not satisfactorily corrected. At the end of the war, Unit No. 1, with a capacity for 15,000 pounds of anhydrous ammonia daily was the only operation at Plant No. 1 completed and in tentative operation. Its duplicates, Unit No. 2 and Unit No. 3, of double capacity, were only partly built. Continuous operation of the entire plant was never realized and but a comparatively small amount of ammonia was produced. This modified Haber operation was frankly projected as a trial of ammonia synthesis and of the funds for its erection, $53,369.43 was supplied out of the nitrate supply fund of the National Defense Act. The extension of the project to produce ammonium nitrate converted the plant into a defense factory, so that the balance of the $12,887,841.31 came from security and armament funds. Of the total cost, $1,597,978.26 was for the permanent village; $503,369.43 for land; $198,223.26 for roads, walks, grading, etc.; $710,476.12 for expenses incidental to operations. The cost of the plant itself and its equipment was $10,877,794.24. After the Armistice the Ordnance Department finished building the village, but curtailed other construction work. Operations ceased during January and the plant was put in a stand-by condition.

As an actual wartime producer of fixed nitrogen and the bone of contention in the long wrangle over the disposition of Muscle Shoals, United States Nitrate Plant No. 2 is an operation of great technical and historical interest.[5] From the very beginning some engineers were skeptical of the quantity and regularity of the water flow at Muscle Shoals. To provide against this uncertainty, and also to save time, it was agreed that while the power-plant buildings at the new Wilson Dam should be built to accommodate equipment for the required 90,000 kilowatts of power, nevertheless the initial installation would have a capacity of only 60,000 kilowatts. The deficiency in power was to be made good by the Alabama Power Company from its hydroelectric plant on the Coosa River and its steam-generating plant known as the Warrior Station.

The contract, signed December 4, 1917, specified that the Company should install at its expense the means of transmitting continuously 30,000 kilowatts of 60-cycle alternating current at 110,000 volts to its Warrior substation and should expand, at the Government's expense, the Warrior Station by building an additional power plant with a 33,333-kilovolt-ampere steam turbogenerator, a transmission line from the Warrior River to Muscle Shoals, and a new substation at the Shoals. For these extensions to its service the Alabama Power Company was to receive $60,000, in addition to a fee of 6 per cent on the cost of construction and equipment, and was to be paid 6½ mills per kilowatt-hour of energy delivered at Muscle Shoals.

Although the new Warrior power plant was delayed due to the inability of the War Industries Board to "clear" the required turbogenerator, the Alabama Power Company's extensions were completed May 23, 1918, eight days before scheduled time. In the meantime the government-built power plant at Muscle Shoals was similarly delayed. Not until August 5 did the General Electric Company's crew arrive to install the 30,000-kilowatt turbogenerator. On September 25 the boilers were fired, and although there was considerable turbine trouble, the operation was satisfactory and supplied power for the first test runs.

Building and equipping this cyanamide plant was placed by the Air Nitrates Corporation with three firms: Westinghouse, Church, Kerr & Company, the J. G. White Engineering Corporation, and the Chemical Construction Company. The two former received 6 per cent of the total cost of the work; the latter, which built the nitric acid plant, 8 per cent with a maximum fee of $240,000. In peacetime and in a settled community with good roads and railroad facilities, it had taken eleven months to construct the American Cyanamid plant at Niagara Falls and equip it with foreign-built machinery.[6] This was a widely heralded achievement of which the Company and its staff had been justly proud. The Muscle Shoals plant, built literally in the wilds of the Tennessee foothills, equipped with American-made apparatus for seven times the capacity, was built in the midst of war with its resulting shortages of labor and materials during a season infamous for its cold, snow, and rain, and was completed in less than a year from the date of first preliminary figures set on paper to time of actual production.[7]

The first groundwork started at the Muscle Shoals site within a week after signing the contract and the first material was delivered December 19, 1917. The winter was exceptionally severe—an unprecedented temperature of 8° F. was registered—so that during January and February construction work was held up badly. Since there was little surplus housing in the region the first pressing need was for quarters for the workmen. The number of male employees, which in August 1918, reached a peak of 19,263, was swelled by their families to over 25,000 The first permanent work on the powersite had been begun in January by the White crews, but so bad were working conditions that as late as March first, except for the railroad yards built by the Southern Railway, practically no permanent construction had been completed.

The first installation of equipment was made April 30 in the nitric acid plant. This was designed according to the plans of Dr. Landis to consist of 12 units, each with capacity to treat 2,500 cubic feet per minute of gas containing 8 per cent nitrous oxide. The cyanamide plant layout and equipment, also designed by Dr. Landis, followed closely the Niagara Falls pattern and consisted of coal-fired lime kilns from which the lime, with finely powdered coke, was fed into large carbide furnaces. The resulting calcium carbide was tapped off, cooled, ground, and fed into electric ovens where the carbide was highly heated in the presence of nitrogen supplied by an installation of Claude nitrogen columns.* The pigs of calcium cyanamide were next powdered and hydrated to destroy any free calcium carbide. The purified, ground calcium cyanamide was then removed to the ammonia unit where, in steel cylinders, it was subjected to high-pressure steam and ammonia gas liberated.

Just as at Plant No. 1, part of the ammonia was oxidized to nitric acid by the method, using a platinum-gauze catalyst, which had been worked out at the Ammo-Phos plant at Warners, New Jersey. The resulting nitric acid was neutralized with the remaining ammonia to form the ammonium nitrate solution, which was crystallized out. At Plant No. 2, the rated daily capacities in the production of ammonium nitrate were: calcium carbide, 475 tons; crude cyanamide, 600 tons; ammonia gas, 150 tons; nitric acid, 260 tons; and ammonium nitrate, 300 tons.

The first operation was in the liquid-air plant where the compressors started October 23, 1918. At 12:02 P.M., October 26, the electric current was turned on the carbide furnaces. The first nitric acid was produced November 19, the first ammonium nitrate, November 25. One month, therefore, elapsed from the starting of the carbide furnaces to the production of the finished nitrate which was turned out exactly two weeks after the signing of the Armistice. Save for the customary troubles associated with breaking in a new set of apparatus, the operation proceeded smoothly from the first and the product met all the exacting specifications of Army inspection.

An adequate supply of limestone for this operation proved an unexpected difficulty. Foster & Creighton, operators of the Rockwood Quarry and crushing plant, about 26 miles from Muscle Shoals, had contracted to deliver 500 tons daily from July 1 to December 31, 1918, and thereafter 1,000 tons a day. Despite additional equipment, the Rockwood Quarry provided an inadequate supply, and in March 1918, the Waco Quarry, six miles east of Russellville, Alabama, was selected as a supplementary source. The actual purchase of the 440 acres comprising this quarry site was not completed until January 4, 1919.

United States Nitrate Plant No. 2 cost the Government $75,181,-

---

* Patents for this process were controlled by the Air Reduction Co., and the Air Nitrates Corp., acting for the Government, contracted for their installation and use and paid royalties till Jan. 1, 1931: on commercial cyanamide, $0.522 per ton; on ammonium nitrate, $1.16; on ammonium sulfate, $0.594. (See Col. J. H. Burns, Hearings Graham Comm., Jan. 7, 1920; original contracts, pp. 2856-67. See also G. J. Roberts, Hearings Agr. & Forestry Comm. on S. 3390, Mar. 1920, p. 97.)

528.41.* Of this $69,022,669.20 was for the plant proper, $4,979,782.22 for the electrical transmission lines and substations, and $1,179,076.88 for the Waco Quarry.

The 1918 nitrate program called for 1,100,000 gross tons for munitions, 215,000 for chemicals, 185,000 for commercial explosives, 300,000 for fertilizer, a total of 1,800,000 gross tons.[8] In anticipating the munitions requirements of the greater American Expeditionary Force already in training, it was self-evident that these schedules must be stepped up for 1919. The Assistant Secretary of War and the Chief of Ordnance, General C. C. Williams, sat down with Messrs. Baruch, Summers, and MacDowell of the War Industries Board to study this problem. They reached two conclusions. First, in the urgent emergency, cost was no object and the cyanamide process offered the quickest, surest means of nitrogen fixation available. Second, this nitrogen should be converted to ammonium nitrate. The logic of the first conclusion was bulletproof; that of the second presented a radical chemical change in ordnance technique.

When we entered the war, the only disruptive for mobile artillery shells approved by the Army was 80° TNT. Because of the shortage of toluene, then produced only from coal tar, it was plain that trinitrotoluene could not be produced in sufficient quantity to load all our ammunition. American munitions makers who had been selling ammonium nitrate to the Allies, therefore called the attention of ordnance officers to this material as an inexpensive, effective extender of TNT as a loading charge. From the first, the Germans had so employed it and the French quickly followed their lead.

Before the war, production of ammonium nitrate in the United States was small † and the chief uses were in safety explosives, dynamites for mining, and for chemical conversion to nitrous oxide, the anesthetic. The small quantities sold in the open market brought a low price, but after the Tariff of 1913 became effective, this rose to 6½¢ a pound, ex docks, New York. Shortly after the war began, the price jumped to 11¢ a pound, and by May 1917 it reached 20¢.[9]

Several American explosives manufacturers were making their own ammonium nitrate and when imports from Scandinavia stopped, they turned more and more to the neutralization of weak acid—a waste from the manufacture of smokeless powder—with ammonia from by-product

---

* F. S. Washburn testified at the Senate Agr. & Forestry Comm. hearings on S. 3390, April 1920, that $62,300,000 had been spent on buildings and equipment. (See Hearings, p. 109.)

† The Tariff Comm. figured 1914 production at 29,891,837 lb., imports, 2,765,728 lb.; Asst. Sec'y War Crowell put prewar production at 58,000,000 lb. per yr.; and the War Ind. Bd. estimated 1914 imports between 6,000,000 and 8,000,000 lb. The Tariff Comm. figures are doubtless the most accurate.

coke ovens, from cyanamide, or the gasworks. The process was rather expensive since these raw materials had to be distilled, the acid with lime and the ammonia with sulfuric acid.[10] The maximum possible output from these sources could not exceed 6,000,000 pounds a month. This production of ammonium nitrate was practically all contracted by the French and Italians who were mixing it with TNT to make Amatol, which was cheaper than TNT and safer to handle. Amatol was officially adopted by the United States Army in October 1917, as a bursting charge for high-explosive shells.[11]

Almost immediately it was discovered that supplies of ammonia and nitric acid were insufficient to produce appreciably greater quantities of ammonium nitrate, especially since ammonia was sorely needed for refrigeration purposes to preserve foodstuffs at the many training camps being built all over the country. The possibility of producing ammonia from ammonium sulfate was considered, but it would have cost much in equipment and time.[12] This situation led to the provisions to produce ammonium nitrate at Nitrate Plants Nos. 1 and 2, and was the basis of the proposal for further production via the cyanamide route, made by the Nitrates Commission in its report on March 30, 1918.

Again the American Cyanamid Company was approached and after protracted negotiations a new agreement signed, covering not only the construction at Muscle Shoals, but also an additional project to be known as Nitrate Plant No. 3. This contract fixed a maximum fee to the Air Nitrates Corporation at $1,500,000.*

It was first suggested to duplicate the Muscle Shoals plant at Kingsport, Tennessee, but the Electrical and Power Equipment Section of the War Industries Board protested that the generators necessary to equip a 90,000-kilowatt station could not be supplied. Next it was recommended that Plant No. 3 be built in two identical units, each with half the capacity of Muscle Shoals: Plant 3A at Kingsport and 3B at Clinton, Tennessee, power to be supplied by the Tennessee Power Company. Finally it was decided to locate 3A, now known as United States Nitrate Plant No. 3, outside Toledo and 3B, to be known as United States Nitrate Plant No. 4, at Cincinnati.

Lessons learned in building Plants Nos. 1 and 2 were taken to heart and important innovations made in the organization and control of the construction job. To avoid divided responsibility, Frederick L. Cranford was appointed director of construction for both plants, and to avoid duplication, he set up at each a single, responsible deputy to

---

* Maj. J. H. Burns of Ordnance testified in Apr. 1922 that the Government paid the Air Nitrates Corp. only $1,150,000, the balance being withheld because F. L. Cranford, dir. of nitrate plant construction, thought that, in view of the incompleted work, this was all the fee earned. (See Hearings Agr. & Forestry Comm. (Sen. 67:2) on S. 3420, p. 81.)

expedite materials, labor, and transportation. In order to take advantage of the commandeering powers of the Army, Brigadier General R. C. Marshall, Jr., in charge of the Construction Division, and Colonel Joyes, Chief of the Nitrate Division, recommended, on July 31, 1918, that the completion of Plant No. 2 and construction of Nos. 3 and 4, be placed under the control of the Construction Division of the War Department. This was promptly approved by the Assistant Secretary of War.[13]

The new plants were half-sized duplicates of Muscle Shoals and construction of both got promptly under way early in August 1918. The general contractors at No. 3 were Bates & Rogers Construction Company of Chicago, and for No. 4, George A. Fuller & Company of New York City. For both plants the nitric acid and ammonium nitrate units were built by the Chemical Construction Company which had the same job at Muscle Shoals. Neither plant was completed upon the signing of the Armistice, and on December 2, 1918, Benedict Crowell, Director of Munitions, directed that all work be discontinued at both, save the completion of a few smaller buildings which were already nearly finished and which might be used for storage purposes; that all outstanding subcontracts for buildings, materials, and equipment be canceled; that negotiations be opened to adjust all claims. For land, labor, materials, and equipment, the gross expenditure for Plant No. 3 was $7,193,670.30, for Plant No. 4, $7,321,373.17.*

Complete exchange of technical information with our British Allies resulted in building the most successful ammonium nitrate production actually in operation at the end of the war. This cooperation, in effect also with the French, was exceedingly beneficial, and in chemical matters at least, we gave quite as much as we took. Even in the case of this distinctively British process,[14] we could make worthwhile contributions to higher yields and large-scale operation.

This so-called Brunner-Mond process involved the formation of ammonium nitrate by direct joint decomposition of coke-oven ammonium sulfate and of Chilean sodium nitrate. As early as 1916 the Atlas Powder Company, which was supplying large quantities of explosives to the British Army, established a research laboratory at Reynolds, Pennsylvania, under the direction of Dr. M. C. Burt, who was shortly succeeded by Roy L. Hill.† Here important work was done

---

* An illuminating note on the high costs of wartime government-built operations was revealed before the Graham Committee when the appraisal value of Plant No. 4 was shown to have been set at $3,199,982.25 as of June 1, 1919, and the salvage value received eventually was $558,382.49. (See Hearings, Nov. 21, 1919, p. 2485.)

† Hill was trained at Swarthmore (A.M., 1909) and after 6 years with du Pont went to Atlas as asst. dir. of the Reynolds Experimental Lab., becoming dir. in 1917 and remaining in charge till 1920, when he moved to the head of the Chemical Service Section.

on detonators, early experiments were undertaken that led to the development of mannitol and sorbitol, and preliminary studies made of the Brunner-Mond process. This last was a pertinent subject for research, since Atlas was at this time the largest American producer of ammonium nitrate.[15] Naturally, the Ordnance Department therefore requested Atlas to investigate the Brunner-Mond process and in November 1917, Major C. T. Harris of Ordnance went to England, accompanied by James T. Power, G. C. Given, W. D. Craig, and P. W. Parvis of the Atlas technical staff. They returned within six weeks and rendered a highly favorable report, but warned that successful operation of the process required very exact control of atmospheric conditions, a problem that was going to be more acute in the United States than in the mild, equitable climate of Great Britain.[16]

Air conditioning was at the time in an embryonic state and this project would require the largest installation to control temperature and humidity ever undertaken. Nevertheless, the need was so great and the process so well approved that the Ordnance Department decided to go ahead. Because of its abundance of fresh water, good rail facilities, and proximity to shell-loading plants, a site was selected on the Susquehanna River at Perryville, Maryland.*

Besides the air-conditioning unit, this plant established other records—to provide the 30,000,000 gallons of water used daily required the largest centrifugal pumps yet installed; sixteen cast-iron pots said to be the largest ever cast with bottoms integral with the sides, were used in handling the solution; more than five and a half miles of crystallizing pans were installed.[17] Despite the size of the operation and the fact that plant construction must be fireproof throughout and housing facilities provided for 6,500 workmen, this Perryville plant, where actual construction work started April 30, produced its first ammonium nitrate on July 8. Initial output was small, but it was increased as construction was completed. Although the British operation upon which the Perryville plant was modeled was in operation before ground was broken in Maryland, the American daily output exceeded the British when the war ended[18] and was nearly double the entire ammonium nitrate capacity of all American chemical industry at that time.[19]

The Perryville plant cost $12,976,401.20. It was practically completed and in operation, but the Army determined to salvage the whole installation. However, a bill passed Congress, turning over to the Public Health Service all housing facilities and all parts and equipment not required by the Ordnance Department.[20]

Strictly speaking, Perryville was not a nitrogen operation, but the

---

* For description of Perryville plant by E. W. Maynard, see Vol. III, Appendix XLVII.

Navy undertook a true fixation plant during wartime. This project was entered into after conference with the Nitrate Division, because during the latter part of 1917, the Navy raised its schedule of munitions requirements far beyond what had been anticipated. The process chosen was direct ammonia synthesis as modified by the General Chemical Company's process. But instead of water power, coal was planned. A site was chosen at Indianhead, Maryland, and the plant was to have a rated capacity of 60,000 pounds of ammonia with a daily production of 180,000 pounds of 96% nitric acid to be produced by catalytic conversion and concentration. Plans had been drawn and the contract let in September 1918 to the J. G. White Engineering Corporation; buildings and installations to be completed within a year, at a total cost of $9,000,000. But the prospects of peace were so good that the entire project was scrapped on November 5, 1918, while still in the blueprint stage.[21]

REFERENCES

1. Basic source material, Nitrate Div. (Ordnance), *Report on Fixation and Utilization of Nitrogen*, 1922, pp. 266-75, 315-23.
2. Hearings Agr. & Forestry Comm. on S. 3420, May 1922, p. 693.
3. C. L. Parsons, Hearings Mil. Aff. Comm. on Muscle Shoals Propositions (House 67:2), Mar. 1922, p. 1134.
4. Details given by R. S. Tour, *J. Ind. Eng. Chem. 12*, 844 (1920); C. H. Jones, *Chem. Met. Eng. 22*, 1071 (1920); J. C. Boyce, *ibid. 17*, 328 (1917); R. Earle, Rept. Chief of Bur. Ordnance (Navy), 1919.
5. Nitrate Div., *op. cit.* pp. 275-86, 325-42; C. H. Bromley, *Power 49*, 424, 482, 558 (1919); A. M. Fairlie, *Met. Chem. Eng. 20*, 8 (1919); E. R. Welles and W. A. Shoudy, *Elec. World 73*, 729 (1919).
6. W. S. Landis, Hearings Subcomm. No. 5 (Ordnance), Select Comm. Expend. War Dept. (House 66:1-3), Feb. 24, 1920, p. 3764.
7. *Ibid.* p. 3761.
8. MacDowell, *Problems of Muscle Shoals*, p. 13.
9. War. Ind. Bd., *Price Bull. No. 56*, 10.
10. Van Gelder and Schlatter, *History of Explosives Industry in America*, p. 954.
11. C. C. Williams, Hearings Agr. & Forestry Comm. on S. 3420, Mar. 22, 1920, p. 27.
12. J. H. Burns, Hearings Subcomm. No. 5, *op. cit.* Jan. 7, 1920, p. 2846.
13. *O.P.D. Reptr.* 94 (Sept. 9, 1918); *Drug Chem. Mkts.* 10 (Sept. 11, 1918).
14. F. A. Freeth and H. E. Cocksedge, U. S. Pat. 1,051,097, assigned to Brunner-Mond & Co.
15. Van Gelder and Schlatter, *op. cit.* pp. 472, 954.
16. W. B. Williams, *History of Manufacture of Explosives for World War*, pp. 39-64.
17. *Ibid.* p. 47.
18. Brown, *Story of Ordnance in World War*, p. 94.
19. Crowell and Wilson, *Armies of Industry*, I, p. 172; Williams, *Munitions Manufacture in Philadelphia Ordnance District*.
20. Burns, *op. cit.*
21. *O.P.D. Reptr.* 28 (June 10, 1918); 29 (June 17, 1918); 27 (Nov. 18, 1918).

Chapter 11

POSTWAR NITROGEN PROBLEMS

UNSUCCESSFUL EFFORTS TO SELL U. S. NITRATE PLANTS—GOVERNMENT OPERATION FOR FERTILIZER PRODUCTION GAINS POLITICAL BACKING—FORD AND OTHER OFFERS FOR MUSCLE SHOALS—GRAHAM COMMITTEE INVESTIGATES NITRATE PROGRAM—GLOOMY OUTLOOK FOR NITROGEN FIXATION.

ON ITS NITROGEN-FIXATION program the Government had spent in the neighborhood of $107,000,000.[1] Only one plant, the cyanamide No. 2 at Muscle Shoals, was ready for production. The near-by synthetic-ammonia plant was virtually completed, but obviously needed further revision. The two remaining cyanamide plants were only one-third completed. The Navy's synthetic-ammonia project had just started.

When the bugle sounded "Cease firing," the critical pressure to produce nitrogen for munitions was immediately relieved. Indeed the urge of the entire war effort snapped, and in perfectly natural reaction, many men in Washington would have dropped the incomplete nitrogen-fixation program like a hot potato; dismantling the plants; salvaging land, buildings, and equipment; writing off losses to the price of victory.

Had it been possible to dispose of the nitrogen plants quickly, they would probably have been scrapped in this summary fashion. The astonishing collapse of the enemy, however, had given little chance to taper off war activities. Into every office in Washington the sudden peace dumped a tangled stack of incomplete blueprints, half-fulfilled contracts, purchase orders and shipping instructions that were now senseless, and hundreds of thousands of letters and telegrams seeking instructions, protesting cancellations, filing claims. Except for arbitrary stop orders which were issued wholesale, prompt decisions simply could not be made and stop orders did not solve the nitrogen problem.

The war had driven home the fact that nitrogen self-sufficiency, only to be achieved through atmospheric-nitrogen fixation, was vital to the defense and feeding of the nation. That lesson was clinched by fuller knowledge of Germany's dependence upon synthetic ammonia during the struggle and of her enormous development of the Haber process. Lieutenant R. E. McConnell of the Navy Bureau of Ordnance, sent to Germany after the war to investigate these operations,* reported that the Ludwigshafen plant with its annual capacity of 100,000 tons of nitric acid, had worked 24 hours a day from early 1915 to the end of the war with only a 12-hour shutdown to repair bomb damage.[2] Army and Navy officers and other men unwilling to forget immediately the bitter lessons of our nitrogen crisis, were convinced that this hard-won experience and heavy plant investments ought to be capitalized.

For a number of reasons, which at the time appeared quite valid, it seemed unlikely that private capital would develop a synthetic-nitrogen industry in the United States. The end of the war meant resumption of the Chilean nitrate trade, and it was well known that not only had the *oficinas* been expanded and modernized, but also that producers in Chile were organizing to present a solid front against any possible synthetic competition. Furthermore, the production of ammonium sulfate had been enormously expanded and competent agronomists prophesied that our new by-product coke ovens were now able to supply all the inorganic nitrogenous fertilizers American farmers would need for several years to come. Finally, although there were wide variations in the cost figures calculated by different experts, grave doubts existed as to the ability of any fixation process, operating under American conditions and American labor and power costs, to compete successfully with the natural and by-product sources of the element.

Due to strictly chemical developments in the next decade, most of these arguments proved to be fallacious. Chilean nitrate irreparably lost control of the world nitrogen market. Domestic by-product ammonia from the coke ovens proved utterly inadequate to meet the fast-growing demands of the refrigeration industry and of agriculture. There was thus created a legitimate economic basis for the development of a synthetic-ammonia industry in the United States, which was quite unforeseen in 1918.

At that time, however, American advocates of adequate nitrogen preparedness were convinced that the Government must support some sort of program that would, at the very least, maintain in stand-by condition enough fixation capacity to guarantee against a recurrence of the ammunition crisis of the late war. On the details of this program they split sharply into two camps. The first group wanted the Gov-

---

* "McConnell made an unauthorized inspection of the Oppau plant which our Peace Commission did not like. Later a walk-through-the-plant inspection was arranged for F. G. Cottrell of the Bur. Mines and party. The Germans were strongly disinclined to give up any information or have the works looked over by any chemical people. Cottrell was awed by the size of the reaction chambers at Oppau—some at least 48 in. in diameter and quite high. Compared with them, the equipment at our No. 1 Plant at Muscle Shoals were pigmies." (C. H. MacDowell, to author, Oct. 17, 1942.)

ernment to turn over the war-built plants to private industry upon such liberal terms that they would constitute a virtual subsidy. The second and initially the smaller, less influential group advocated government ownership of sufficient fixation capacity to serve as a backlog for emergency military requirements. They did not originally propose that these plants be operated in peacetime.

An intricate, possibly inevitable sequence of economic, chemical, and especially political events changed the thinking of Washington on nitrogen plants from "scrap 'em and sell 'em" to what eventually developed into the Tennessee Valley Authority.

Eight days after the Armistice, November 19, 1918, Assistant Secretary of War Crowell called a conference. One definite decision was reached. Plant No. 2 must be completed and operated to prove out its efficiency, but no more money should be spent than absolutely necessary to demonstrate the plant's usefulness for munitions and commercial manufacture.[3] It was also decided that work on the incompleted Plants Nos. 3 and 4 should be suspended and the most advantageous terms for their disposal investigated. The fate of the Sheffield synthetic-ammonia plant, it was agreed, could only be determined after further study.

At this stage Arthur Graham Glasgow, an energetic Virginia engineer, stepped into the nitrogen picture. He had an international reputation in the gas-utilities field and had gone to Rumania for the Red Cross in 1917. In 1918 he joined E. R. Stettinius in France to assist in Allied war purchases, particularly explosives. This war-won experience convinced him of the soundness of private development of the nitrogen industry, and after visiting the Muscle Shoals and Sheffield plants at the request of the War Department, he recommended[4] that a commission be sent to Europe to study the plants and make comprehensive recommendations as to the future of air nitrogen in the United States. Although Glasgow's recommendations were approved by the Assistant Secretary of War on January 14, 1919, it was not until March 29 that the Secretary of War acted on them. By this time the sentiment for government operation of the plants was already beginning to crystallize.

Shortly after the Armistice, the General Chemical Company made an offer for the Sheffield synthetic-ammonia plant. It proposed to operate the plant for one year, provided that if money was lost, it would have the opportunity to recoup by operating a second year. The Company agreed, after deducting the costs of experiments, fixed changes, and operation, to turn all profits over to the Government. Negotiations on this proposal, carried on from January until June 1919, hung up because the Company could not agree to the Ordnance Department's offer of three years' free use of the plant if the Company spent at least $500,000 in perfecting the operation and guaranteed its success.[5]

While these negotiations were pending, Glasgow tried to work out with Washburn a definite program for the Muscle Shoals cyanamide plant. From the first Washburn, representing the American Cyanamid Company, contended that its plant at Niagara Falls was quite capable of supplying the entire North American demand for cyanamide. When the Government experts conceded this and proposed to install sulfuric acid units salvaged from the Government's Old Hickory powder plant and to convert a large part of the ammonia to ammonium sulfate, he pointed out that this roundabout method could not possibly compete with by-product sulfate from the coke ovens. The Company stood ready to operate the plant for the production of cyanamide, cyanide, ammonia, or ammonium nitrate, provided that the output of any or all of these chemicals was purchased by the Government for explosive purposes only. It stated emphatically that it could not manufacture any form of nitrogenous fertilizer without subsidy from the Government. No way was found of reconciling the conflicting views.

When negotiations with both companies directly involved in Plants Nos. 1 and 2 bogged down, Glasgow and Major D. P. Gaillard of the Ordnance Department went out to sell these plants to private interests.[6] The most logical prospect was some large fertilizer company and they called first on the presidents of all the leading corporations. Some expressed interest, but all dropped the proposal as soon as they learned that by law the properties could only be leased for five years and then with the proviso that the Government might, at any time, give thirty days' notice and take the property back. Upon such terms, even the tempting offer of the Government to add a sulfate of ammonia unit, provide storage and bagging facilities, and lease the completed plant for half the net profits, failed to secure a single formal offer.

Next Glasgow and Gaillard approached important New York financial interests to organize a company to operate these plants. So lukewarm were these financial houses, they would not even investigate the properties. As a last resource coke-oven interests were approached, but with the same result. In Major Gaillard's own words, "There seems to be a decided antipathy of capital to engage in any partnership arrangement with the Government."[7]

This antipathy was not surprising. Throughout the war the Government had shown itself to be a difficult customer, dictatorial and arbitrary, forcing extraordinary demands, compelling the use of voluminous, time-consuming, irksome forms, and paying its bills in its own good time. At the end of the war it ruthlessly canceled thousands of contracts and while it did offer to settle claims, too often it did so with a cold-blooded disregard, not only of the rights, but of the feelings also of the party of the second part.

In the long run this jettisoning of the whole war business was advantageous to the national economy. It forced a swift, if cruel, readjustment to peacetime conditions. But it set an example that filled the courts with suits over repudiated obligations and it was, moreover, an important element in the demoralization of commodity prices which led to the debacle of 1920. With these experiences fresh in their memories, it is little wonder that fertilizer manufacturers and financial interests received the Government's nitrate proposition with conspicuous lack of enthusiasm.

In setting up the original nitrogen program before Congress, it had been indicated that while military requirements were paramount, nevertheless, nitrogen closely touched the interests of the farmer. While Glasgow was endeavoring to dispose of the nitrogen plants to private interests, several senators and representatives from agricultural states awoke to the fact that these plants were potential producers of various nitrogenous fertilizers and that cheap fertilizer, produced and distributed under government auspices, was capital political ammunition. They began, therefore, to press this plant-food issue. On March 20, 1919, the Secretary of War appointed Glasgow Fixed Nitrogen Administrator,* charged specifically with the disposition of the nitrate plants, and authorized the Ordnance Department to take over the abandoned Ohio Laboratory of the Chemical Warfare Service at the American University in Washington and to convert it into the Fixed Nitrogen Research Laboratory. Here all nitrogen studies were to be centralized in a clearinghouse to coordinate the work of the Navy, Interior, and Agricultural Departments, in order that—and this is significant—"the Government nitrate plants should be developed to the greatest peacetime service for fertilizer and other purposes."

At the same time the Secretary appointed the United States Fixed Nitrogen Commission, with Colonel J. W. Joyes of Ordnance as chairman, the other members being Lieutenant Colonel A. B. Lamb of the Chemical Warfare Service, and Lieutenant Colonel F. H. Wagner and Captain R. S. Tour, also of Ordnance. This commission sailed for Europe on June 6, 1919, and made a thoroughgoing inspection, first of the French cyanamide plant, then of the Haber-Bosch operations at Oppau and Merseburg. After this they divided, Wagner remaining in France, Lamb and Tour going to England, and Joyes visiting the arc-process plants at Notodden and Rjukan in Norway.

Upon their return the Commission wrote an exhaustive report which

---

* Succeeded by his deputy, George J. Roberts, on Nov. 3, 1919, when Glasgow went to Europe as special representative of the Secretary of War.

was summarized by the Fixed Nitrogen Administrator Glasgow in his letter of October 22, 1919.[8] A scrupulous study had been made of American nitrogen supply and demand and of the comparative value of various nitrogenous fertilizers. Particular emphasis was placed on the Muscle Shoals plant; what fertilizers it could best manufacture; what it would cost to convert it into a fertilizer operation; and what the probable cost and sales values of the selected materials would be. The conclusions, in the words of Major General C. C. Williams, Chief of Ordnance, were that "there seemed to be no reasonable doubt that the art of nitrogen fixation should be developed, that No. 1 Plant should be made effective, that No. 2 Plant should be operated, and that the Wilson Dam should be completed and its power made available for No. 2 Plant . . . that real nitrogen preparedness could only be accomplished at the present time by the Government itself, and . . . that all government nitrogen-fixation activities should be centered in a corporation that was able to operate through regular business methods in order to obtain the many and manifest advantages thereof." [9]

To effectuate this radical proposal—a government-owned industrial corporation to operate a chemical plant—Senator Wadsworth introduced the bill S. 3390,[10] on November 3, 1919, identical with H.R. 10329 which was introduced into the House by Representative Kahn. The conception of a government-owned corporation, exempt from all federal, state, and local taxes, conducted by a board of directors appointed by the Secretary of War at his pleasure, and endowed with all the powers of any private corporation, was an innovation. The bill provided that all net earnings should be used: (a) to pay the Government 5% dividends on $12,500,000 preferred stock; (b) to develop and improve the plant and equipment; (c) to create a reserve of $2,500,000; and (d) to pay over the remainder to the United States Treasury. Here was a new variety of political plum whose juicy lusciousness was apparent to all.

During the five weeks' hearings [11] the bill had energetic support from government officials and from four strong farmers' organizations: the Farmers' National Council, the National Board of Farm Organization, the National Grange, and the American Farm Bureau Federation. The War Department supported the bill vigorously and Secretary of War Baker; Major General Williams, chief of Ordnance; Colonel Burns, Colonel Joyes, and Mr. Roberts of the Nitrate Division; and Dr. Arthur B. Lamb, director of the Fixed Nitrogen Research Laboratory, all appeared personally in its favor. Other supporting witnesses were Prof. Milton Whitney, chief of the Bureau of Soils, and the Washington representatives of the above-mentioned farm organizations: Benjamin C. Marsh, Charles A. Lyman, T. C. Atkeson, and Nat T. Frame.

Opposition was vigorously voiced by Frank Washburn and Dr. Walter S. Landis on behalf of the American Cyanamid Company, which by the terms of its original contract with the Government had optional rights to buy the Muscle Shoals plant, and also by the National Fertilizer Association which sent a letter of protest to the Committee on May 14, 1920. The fertilizer manufacturers were properly alarmed at this threat of government competition, for the fertilizer possibilities of these fixation plants were looming larger and larger. The various branches of the chemical industry were then more sharply individualized and the leaders of each did not so readily identify their common interests.[12] After passing the Senate, this bill died in the House Committee on Military Affairs, which failed to bring it to the floor before the adjournment of the Sixty-sixth Congress on March 4, 1921.

Proposals for government operation were interrupted July 8, 1921, by Henry Ford's offer to buy the nitrate plants and the incompleted Wilson Dam lock, stock, and barrel.[13] The cost of completing the dams—a condition of the Ford offer—was estimated at $50,000,000 and upon the advice of Secretary of War Weeks, who considered the annual rental offered for the dams too low, this offer was turned down and Ford submitted a revised proposal on January 25, 1922.[14] This included the purchase of Nitrate Plants Nos. 1 and 2, the Waco Quarry, and the Warrior steam plant for $5,000,000, with the agreement that Plant No. 2 was to produce fertilizers to be sold at not more than 8 per cent profit. The Government was to complete Dams Nos. 2 and 3 and lease the entire water-power development—dams and plants—to Ford for 100 years, for annual rental of 4 per cent of cost with an option to purchase upon expiration of the lease.

A bill [15] accepting this offer was introduced into the House and referred to the Committee on Military Affairs, under the chairmanship of Julius Kahn, which immediately opened hearings to weigh the merits not only of the Ford offer, but of a number of others which had been prompted by his bid. The hearings on H.R. 11903 lasted from February 8 to March 13. Provided the Government would complete the Wilson Dam and powerhouse, the Alabama Power Company made an offer, February 15, 1922, to pay $5,000,000 for the Sheffield steam plant and the Government's interest in the Gorgas-Warrior Station, and to furnish 100,000 secondary horsepower for the Government's use at the nitrate plants.[16]

Frederick E. Engstrum offered to lease the Muscle Shoals plant for 50 years and to produce nitrogen for explosives when needed and for fertilizers in peacetime.[17] His attorney, Marion Butler, testified: [18] "We have also succeeded since the war in making the largest and most efficient electrolytic cell in the world . . . for producing hydrogen gas . . . a 10,000-ampere cell. . . . The largest cell which had before been built and successfully used was 250 amperes. . . ." * And it was emphasized that efficient operation of the Haber-Bosch process depended chiefly on pure electrolytic hydrogen. A third offer was made on March 23, 1922, by Dr. Charles L. Parsons, presumably acting for the General Chemical Company. He proposed to buy Nitrate Plant No. 1 for $600,000.[19]

Although Ford played up the fertilizer aspects of Muscle Shoals, it was judged that his chief interest was in the hydroelectric development. Opposition to his bid, therefore, came chiefly from the water-power and by-product coke interests supported by the Federal Power Commission, the Secretary of War, the National Fertilizer Association, and the American Cyanamid Company. J. O. Hammitt, vice-president of its subsidiary, the Air Nitrates Corporation, reiterated the stand that his company could not operate Plant No. 2 if the Government retained title, except under subsidy. His letter to the War Department, regarding the contract in which the Government gave Air Nitrates preferential rights to buy Plant No. 2, was submitted. It pointed out that the Company did not recognize the opinion of the Attorney General holding this part of the contract invalid, and that it would protect its rights in court.[20]

The chemical opportunity afforded by the proximity of the Tennessee phosphate fields was brought out during these hearings by Theodore Swann, president of the Federal Phosphorus Company. He proposed that the Government use the patents of his company covering electric-furnace production of liquid phosphoric acid, to make ammonium phosphate as a desirable form of highly concentrated plant food.[21]

Final action was the rejection of all bills introduced for the disposal of the Muscle Shoals property.[22] These included the proposal to organize the Federal Chemical Corporation,[23] reviving the proposal sponsored by Secretary of War Baker, as well as the Ford offer[24] upon which the Senate Committee split seven for and nine against.†

While Congress was wrangling over the fate of the nitrate plants, a special section of the Nitrate Division under R. S. Tour was redesigning the synthetic-ammonia operation at Sheffield on a smaller scale, striving to bring this unit into successful operation. The job included not only the construction of new buildings, but also changes in the

---

* About the same time the Electrolabs Co. of Pittsburgh developed, in cooperation with the Fixed Nitrogen Lab., a 10,000-ampere cell and demonstrated its practical, economical operation. [See Nitrate Div. (Ordnance), *Report on Fixation and Utilization of Nitrogen*, 1922, p. 217.]

† Senators in favor of accepting the Ford offer were E. F. Ladd, Arthur Capper, Pat Harrison, T. H. Caraway, J. E. Ransdell, J. Thomas Heflin, and E. D. Smith.

Haber-Bosch apparatus, and the installation of an electrolytic hydrogen-generating plant, all estimated to cost $1,023,117.

This program was to have been finished July 1, 1923, but it was never wholly executed because in the interim the Atmospheric Nitrogen Corporation,* subsidiary of the General Chemical and the Semet-Solvay companies, had brought a synthetic-ammonia process into successful operation at Syracuse, New York. The immediate purpose of a practical demonstration of the Haber methods in this country having thus been achieved, the Government forsook further experimental work and the Sheffield plant[25] was put in the most economical stand-by condition.

At the Muscle Shoals cyanamide plant activity also continued after the Armistice. Buildings and apparatus installations were completed, and on January 11, 1919, test runs on two complete lines—a fifth of total plant capacity—were started and continued two weeks by the Air Nitrates Corporation staff under the eye of government representatives. Some 2,200 tons of calcium cyanamide were produced and about 1,700 tons of ammonium nitrate. Tune-up adjustments were necessary, but no serious alterations, and several units of the installation surpassed rated capacities.

Energy for this test run was supplied by the Government's Warrior Station and transmission line, but the Muscle Shoals power plant was completed October 30, 1919, and after some adjustments was put into regular operation October 1, 1920. Up to November 8, 1919, a total of 9,170,000 kilowatt-hours of power were delivered. The most costly postwar addition to No. 2 Plant, however, was the Waco Quarry, $535,006.60 being paid to the Arthur G. McKee Company of Cleveland for completing an installation to deliver 2,000 tons of crushed limestone per day.

The disposal of the nitrogen plants, delayed by bureaucratic and farm-bloc support of government operation, was now further complicated by purely partisan politics. The Republicans, having won control of Congress, appointed a Select Committee of the House to investigate expenditures in the War Department. It was an orthodox move to embarrass the Democrats and to support Republican charges of extravagances and mismanagement in the conduct of the war. Subcommittee 5 on Ordnance of this general committee, known as the Graham Committee, consisted of William J. Graham, chairman, Albert W. Jefferis, and Finis J. Garrett. It delved deeply into the nitrogen

---

* Organized 1919 with a capital of $5,000,000. Officers: E. L. Pierce, pres.; A. W. Hudson, treas.; Ernest Jones, sec'y; H. H. S. Handy, E. L. Miller, W. H. Nichols, Jr., Henry Wigglesworth, and Harold Otis, dir. (See *Drug Chem. Mkts.* 43, Dec. 17, 1919; *O.P.D. Reptr.* 28, Jan. 12, 1920.)

program at a long series of hearings held from July 17, 1919 to February 8, 1921.

Two flatly contradictory views were expressed in the report of the Committee, submitted May 18, 1920.[26] The majority—Representatives Graham and Jefferis—blasted the whole program as an unnecessary, misdirected, inefficient, costly mistake. The locations of Plants Nos. 2 and 3 were branded as unwise, politically inspired sites. The cost-plus basis of the construction contracts was severely criticized as unduly expensive to the Government and demoralizing to labor. The Ordnance Department—especially Colonel J. W. Joyes—was specifically charged with failure to guard the interests of the Government, notably in the contracts with the Alabama Power Company. It was recommended that the plants should be forthwith scrapped or leased at once to the highest bidder.

Representative Garrett's minority report hit back stoutly. It accused the majority of reaching a preconceived, politically biased conclusion based on scandals and rumors unsupported by sworn testimony. The Chilean nitrate crisis, it maintained, was real. It pointed out that Plant No. 1 had cost $5,502,170.13, not $12,000,000 as stated by the majority. It defended Colonel Joyes warmly, praising him for excellent work done under high pressure. Finally, while it did not condone the familiar evils of the cost-plus system, it showed that this method was commonly used by private contracting firms of the highest integrity and that amid the urgencies and dislocations of wartime construction, it was the simplest, surest, fairest means of getting results.

The truth lay between the extremes of these two reports. Grievous mistakes were made. The enormous expenditures subsequently necessary to provide an adequate, year-round water supply at Muscle Shoals vindicate the criticism of that location as an easily and economically developed powersite. To have placed chief reliance on the untried ammonia-synthesis process was a grave error in judgment. The American Cyanamid Company endeavored, not unreasonably, to protect its valuable patent rights and to forestall government competition. It did produce fixed nitrogen in record time and there was no credible evidence of an attempt to foist on the Government an obsolete process[27] or fraudulently to pile up unwarranted costs.[28] The lengthy negotiations over all contracts indicate that the Ordnance Department was not negligent in protecting the public interest and it certainly had the benefit of the best engineering and legal advice. Costly delays, waste, and extravagant expenditures undoubtedly occurred, as they commonly do in public works, especially in wartime. But they were trivial compared to what the country has since become accustomed and they were offset in some degree by generous, patriotic cooperation on the part of many corporations and by the long hours of overtime unstintedly given by many individuals.

Four years after the end of the war, the Muscle Shoals project had cost American taxpayers $167,163,296.* Omitting the still incompleted hydroelectric development, the Government had, at a cost of over $80,000,000, buildings and equipment to operate the synthetic-ammonia and cyanamide processes. True, the former process had not yet been satisfactory, but in view of the experience at Syracuse, it was doubtless possible to put the Sheffield plant in efficient production in short order and at comparatively little expense. The cyanamide process was ready in stand-by condition.

The conflicting proposals for the disposition of these plants had canceled themselves out. The political hullabaloo in Washington had succeeded in thoroughly frightening off any private interests which might have taken up the development of nitrogen fixation in this country. It was plain, however, that the Chilean monopoly had been cracked, that the world was not going back to dependence upon it. While but 10 per cent of the world's supply of inorganic nitrogen had come from the air in 1913, a third came from synthetic sources in 1917.† At the end of 1918 there were in operation or building 12 arc-process plants, capacity 38,300 metric tons of nitrogen; 35 cyanamide plants, 325,000 tons; 3 synthetic-ammonia plants, 308,000 tons.[29] By 1921, it was estimated that the nitrogen-fixation capacity of the world stood at 672,700 metric tons and that commercial production was actually 604,400 tons.[30]

Within the United States, in 1921, there were two commercial fixation plants and two idle government plants with a probable potential capacity of 48,000 tons. On the Pacific Coast the arc-process operation of the American Nitrogen Products Company had an annual capacity of some 300 metric tons of nitrogen fixed in the form of sodium nitrite. At Syracuse, New York, the synthetic-ammonia plant of the Atmospheric Nitrogen Corporation had a rated annual output of 3,000 tons

---

* As itemized before the Graham Committee's hearings and set forth in its reports, the costs were:

Waco Quarry	$ 1,302,962
Addition to Gorgas steam plant	4,900,000
Nitrate Plant No. 2	66,252,393
Nitrate Plant No. 1	12,887,941
Dam No. 2, cost already to Government	17,000,000
Dam No. 3, required to complete	25,000,000
Dam No. 3, estimated cost to build	25,000,000
Dam No. 3, overflow rights, estimated minimum	1,500,000
Interest on new money required at Dams Nos. 2 & 3	13,320,000
Total cost to Government	$167,163,296

† For world nitrogen production, 1913-20, see Appendix XVII.

of nitrogen. Our normal consumption of inorganic nitrogen was then 113,405 tons, of which 51,013 tons were supplied by the coke ovens.[31] The deficit could be, and at the time largely was, made good by the American Cyanamid plant on the Canadian side of Niagara Falls. Neither statistically nor politically were the prospects bright for private development of a nitrogen-fixation industry in the United States.*

REFERENCES

1. Sen. Rept. 831, July 20, 1922.
2. Crowell and Wilson, *Armies of Industry*, I, p. 309.
3. Memorandum signed by Crowell, Dir. of Munitions, Dec. 2, 1918.
4. Memorandum, Jan. 7, 1919.
5. H. Wigglesworth, Hearings Subcomm. No. 5 (Ordnance), Select Comm. Expend. War Dept. (House 66:1-3), Jan.-Feb. 1920, p. 3496.
6. G. J. Roberts, Hearings Mil. Aff. Comm. on H.R. 10329, Apr. 19, 1920, p. 86.
7. *Ibid.* p. 95.
8. Text, Hearings Agr. & Forestry Comm. on S. 3390, Apr. 1920, p. 89.
9. *Ibid.* Mar. 22, 1920, p. 32.
10. *Ibid.* pp. 3-6 for text. See also *Drug Chem. Mkts. 6*, 1042 (1920).
11. Mar. 22-Apr. 28, 1920, before Agr. & Forestry Comm. (Sen. 66:2).
12. Current news accounts in *Drug Chem. Mkts. 6*, 695, 997 (1920); *O.P.D. Reptr.* 26 (May 24, 1920).
13. Text, Hearings Mil. Aff. Comm. (House 67:2) on Muscle Shoals Propositions, Feb. 9-Mar. 13, 1922, p. 10; abstracted, *Chem. Met. Eng. 26*, 272 (1922).
14. Text, Hearings on Muscle Shoals, *op. cit.* p. 13.
15. H.R. 11903 (67:2).
16. Text, Hearings, p. 776; also House Doc. 192.
17. Text, Hearings, p. 896; also House Doc. 193.
18. Mar. 13, 1922; Hearings, p. 990.
19. Text, Hearings, p. 433; also House Doc. 220.
20. Hearings on Muscle Shoals, *op. cit.* pp. 453, 484; and of Agr. & Forestry Comm. on S. 3420, June 21, 1922, p. 849.
21. Hearings on S. 3420, *op. cit.* May 12, 1922, p. 603.
22. Sen. Rept. 831, *op. cit.*
23. S. 3420 (67:2), introduced by Sen. Norris.
24. S. 3802 (67:3), introduced by Sen. Norris.
25. J. H. Burns, Hearings on S. 3420, *op. cit.* Apr. 12, 1922, p. 59.
26. House Rept. 998 (66:2), 1921, 122 p.
27. C. L. Parsons and H. L. Cooper, Hearings on S. 3420, *op. cit.* May 1922, pp. 426, 721.
28. F. H. Wagner and W. J. Neale reports in Hearings Subcomm. No. 5, *op. cit.* Feb. 3, 1920, pp. 3387-3415 and Apr. 13, 1920, pp. 3889-3922, resp.
29. F. A. Ernst, *Trans. Am. Electrochem. Soc. 51*, 186 (1927).
30. Nitrate Div. (Ordnance), *Report on Fixation and Utilization of Nitrogen*, 1922, p. 66.
31. Ernst, *Fixation of Atmospheric Nitrogen*, p. 135.

* For U. S. production of fixed nitrogen, see Appendix XVIII.

Chapter 12

THE BY-PRODUCTS FROM COAL

FIRST BY-PRODUCT COKE OVENS AT ALKALI PLANTS—STEEL INDUSTRY GRADUALLY FORSAKES BEEHIVE COKING—HIGH PRICES OF BENZENE, TOLUENE, AND PHENOL SPUR U. S. PRODUCTION—GERMAN PLOT DIVERTS PHENOL TO ASPIRIN—POSTWAR DEMAND FOR COAL-TAR CRUDES SURPRISES PRODUCERS.

THE BEEHIVE COKE OVEN has become an American symbol. Coupled always with the adjective "wasteful," it is the classic "horrible example" of American industrial profligacy. Solemn economists have criticized it. Livid crusaders have ridiculed it. It has had many defamers and few defenders. Theoretically, it is quite indefensible; but practically, if one understands where it was built and why it was operated, it needs no defense.

This crude hollow cairn, made of handy stones, quickly erected anywhere, economically operated as a unit by unskilled labor, easily shut down and as easily started up again, is the very antithesis of the vast battery of by-product recovery ovens. This great mountain of metal and expensive refractories, with forests of pipes, valves, and gauges, requires a heavy initial investment, skilled labor, and a big, steady market for its output.

The cheap little beehives suited the needs of our pioneering metallurgy as a nut fits its own bolt. Wherever a seam of coking coal showed adjacent to some iron or copper deposit, these low-cost ovens appeared, produced good, cheap coke, and if either the market or the supply failed—as both frequently did—were temporarily closed or even abandoned with little loss. It was then more profitable to make the coke at the mines than to bring the ore to the coke plants.[1]

The wisdom of Mahomet thus going to the mountain was emphasized by the lack of demand for the very by-products which are the economic reason for installing costly recovery plants. In both the Pittsburgh and Cleveland districts, oven gas had to compete with natural gas which was richer in heat units and exceedingly low-priced. Our chemical industry had little use for coal-tar crudes. Benzol was a solvent, chiefly used for rubber and dry-cleaning, and even when the early recovery plants stripped it from fuel gas, they did so to enrich illuminating gas.[2] The quantity of phenol directly recoverable—this was before the synthesis of phenol from benzene—was commercially insignificant. The two remaining crudes, naphthalene and anthracene, were recovered from the creosote-oil fractions, but at that time crude naphthalene was imported and refined here, while the market for anthracene was very small. Furthermore, creosote oil found ready sale as a wood preservative—in fact, American consumption was twice greater than production—so that in view of the limited call for these crudes, their extraction was not commercially tempting.[3] Tar-distilling practice then also produced about 70 per cent of its tar as pitch. While in Europe coal tar found use only as fuel, here it had a profitable market for roofing, waterproofing, and increasingly for road building.

At this stage of our chemical development, all these crude coal-tar products were largely supplied by tar refiners operating on low-cost by-product tar from the gasworks.[4] Thus the coke plant at gasworks was producing but one chemical, ammonia, which did not have to meet this competition. Either as crude liquor or converted to sulfate, ammonia recovery was a sound, commonly profitable chemical enterprise, but this single product did not justify a by-product coke industry.*

So little financial incentive was there to produce coke by-products, that the first recovery ovens in the United States were an adjunct to a Solvay soda-ammonia alkali plant. In 1893, at its Syracuse plant, the Solvay Process Company built 12 Semet-Solvay ovens developed by its associate company in Belgium. The avowed purpose was to produce raw materials for its own use: ammonia for reaction with brine; coke to burn with limestone; fuel gas to make steam for the ammonia-chloride stills. Six years later, in June 1899, the New England Coal & Coke Company installed 400 Otto-Hoffmann ovens, at Everett, Massachusetts, primarily to produce illuminating gas.† Three years later,

---

* Coke-oven ammonia and ammonium sulfate production, 1912-22, compared with production from other sources, is shown in Appendix XXI.

† "This is not quite accurate. A number of years before, Henry M. Whitney of Boston obtained control of the Dominion Coal Co. in Nova Scotia. His idea had been to supply the New England market, but the coal turned out to be a poor quality almost impossible to burn in plants built for burning high-grade New River coal. To save his investment and find a market for his coal, he built the coke ovens referred to. . . . The gas sold to the Boston Consolidated Co. for use in Boston and suburbs and the coke for household use in competition with anthracite. Later I persuaded this company to erect a small blast furnace for the production of foundry iron, which made a market for Merrimac's pyrites cinder. Early in 1915 I also persuaded the coke works to put in a light-oil plant to save the benzene, toluene, and xylene. This light oil was shipped to Woburn where we refined it in the New England Mfg. Co. and turned the benzene into phenol and picric acid. We built a TNT plant under the design and supervision of Oscar Guttmann & Sons of London, but it blew up before it got into full operation. After this we contented ourselves in selling the pure toluene at a very high price." (Henry Howard, to author, Aug. 23, 1943.)

1902, another by-product coke installation was erected by the Michigan Alkali Works at Wyandotte, Michigan.

Though many early installations were built to produce city gas, the coke being sold locally as industrial fuel, the second by-product plant of 60 ovens was built in 1895 by the Cambria Steel Company at Johnstown, Pennsylvania, to make metallurgical coke. This innovation was regarded skeptically by the iron makers till, in 1899, the addition of 100 more Otto-Hoffmann ovens (later known as United-Otto ovens) proclaimed its practical success. Four years afterwards, in 1904, the Lackawanna Steel Company erected at Buffalo, a really big battery of 282 Rothberg retort ovens, and with the installation of 280 Koppers ovens at Joliet, Illinois, by the Illinois Steel Company, in 1908-9, by-product coking was fairly launched as an accessory operation of our iron and steel industry.[5]

The Koppers ovens at Joliet introduced a new factor in coke-oven construction, the first vertical-flued ovens of silica brick built in America. This plant indicated such an immediate success that Illinois Steel went forward with the building of a large plant to furnish coke for the new blast furnaces and steel plant at Gary, Indiana. Other steel companies, realizing that the development of this oven insured constant operation with low investment and upkeep, soon proceeded with other plants. Such organizations as Inland Steel, Republic Iron & Steel, Toledo Furnace, Corrigan-McKinney, Woodward Iron, Youngstown Sheet & Tube, and Maryland Steel (later Bethlehem Steel) all contracted for this new type of oven. All this was before 1915.

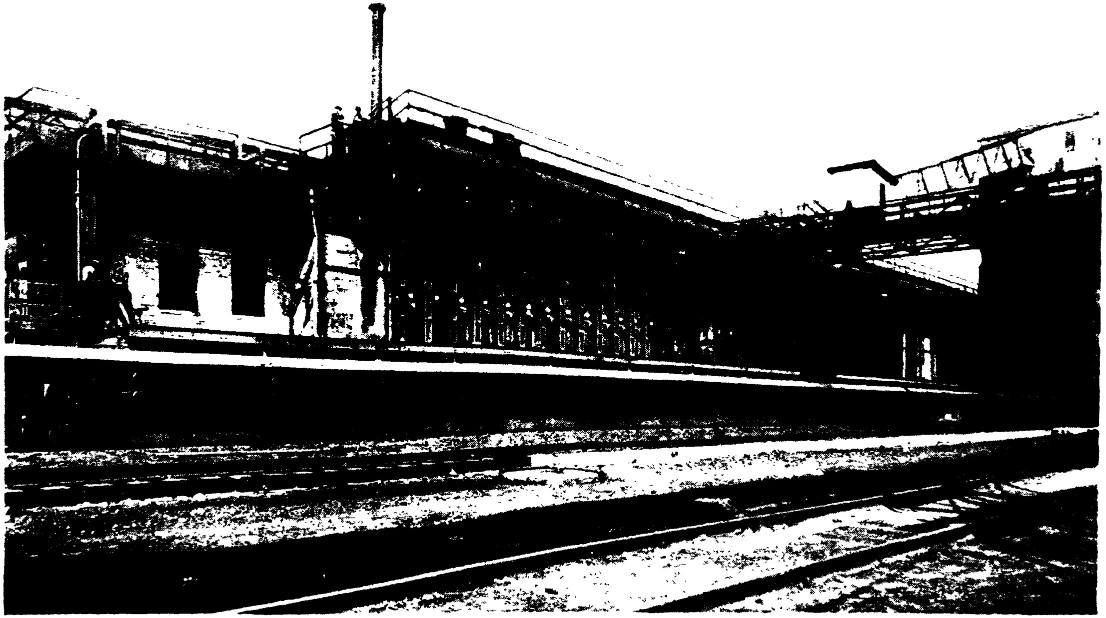
In 1914, Pittsburgh interests under the guidance of H. B. Rust decided that the development of the Koppers ovens in America was worthy of a larger field and a much larger organization. Accordingly, the H. Koppers Company in Chicago was acquired in January 1915, and in March, 67 engineers and executives, having the know-how of Koppers oven construction, moved to Pittsburgh.[6]

Once started, the growth of the by-product coke ovens was steady, due, it must be confessed, less to the by-products themselves than to the increasing use both of furnace and foundry coke and of coke gas for city service.[7] Nevertheless, in 1912, by-product ovens were supplying only a quarter of all our coke and by 1914 still less than a third.*

The gradual switch from beehive to by-product ovens meant a relocation of the coking industry from the mines to the cities. Municipal gas was an important incentive to this geographical revolution. By 1912, some 50,000,000 cubic feet of coke-oven gas were being sold each day for illuminating purposes, almost the entire supply of such impor-

---

* For domestic coke production figures, see Appendix XIX.



Battery of ovens of the Inland Steel Co., Indiana Harbor, October 1917.

tant cities as Boston, Indianapolis, Baltimore, and Milwaukee coming from these sources.[8] Almost without exception the retort-oven operators recovered their ammonia, and because of the growing demand for ammonium sulfate in fertilizers, an increasing quantity was converted to this material.

Recovery of the chemical by-products from coal tar was neglected for lack of a market.* The total value of coal-tar crudes produced in 1914—mostly benzene—amounted to only $997,000.[9] At the end of 1913, sixteen plants were producing so-called light oil,† most of which went toward enriching illuminating gas.[10] Several of these were operated by the Semet-Solvay Company which made a practice of recovering crude benzene at all its coking operations and regularly using it to step up the quality of illuminating gas.[11] Pure benzene and toluene were distilled from crude light oil in two or three small plants, the principal one being operated by the Barrett Manufacturing Company.‡ Refined naphthalene was produced in two plants and used exclusively as a moth preventive. There was but a single producer of phenol, Barrett, and no refiner of anthracene.[12] Much of the coal tar produced was separated only into cresote oil and pitch, which were sold for wood preserving, road building, or roofing.

Tentative starts towards a production of pure coal-tar products had been attempted. Synthetic phenol from benzene had been produced as early as 1900 by the Semet-Solvay Company at Syracuse. For several years an output that reached a peak of 2,500 pounds daily had been

---

* For coal-tar crudes production figures, 1915-22, see Appendix XXII.

† "More correctly, 'gas-benzol,' which closely approximates what the Europeans describe as 'light oil.' Light oil as such was never recovered in this country. It was the first fraction from the distillation of coal tar, but if you get out the gas-benzol in the first place, it never gets into the tar, therefore our tars carry no light-oil fraction." (J. R. M. Klotz, to author, Jan. 29, 1943.)

‡ "The source of this information seems to have been F. E. Dodge, who was at one time supt. of the Frankford Refinery of the Barrett Mfg. Co. and later worked for me putting in benzol-recovery plants at several steel companies with by-product coke ovens. I think he is a little mixed up. Barrett had one principal plant at Frankford which operated regularly on gas-benzol and such light oil as they could get and considerable gas drips and Pintsch hydrocarbon. They made nitration grade of benzene, 90% benzol, and a small amount of pure toluene. . . . The United Gas Improvement plant at Philadelphia, under the late Paul Thompson, was monkeying with production of a few primaries including benzene and naphthalene. Barrett was making considerable phenol and I don't think the primary products industry was in quite so embryonic a state as you point out. I came into the industry in 1909, and at that time, Dr. Harry W. Jayne (manager of Barrett Chemical Dept. at Frankford, later Jayne & Chase before being absorbed by the M. Eheret, Jr., Co.) was considered by the English and Germans to be one of the five world authorities in coal-tar chemistry. He was the father of D. W. Jayne of du Pont, whose assistant I was for many years. If some of the capitalists and bankers who later crept in on this industry would have listened to Dr. Harry Jayne, the industry would have been way ahead of where it was in 1915." (J. R. M. Klotz, to author, Jan. 29, 1943.)

synthesized to picric acid and sold to the United States Army for munitions.[13] Rather optimistically anticipating an American demand for coal-tar chemicals, this company in 1910 joined with Barrett and General Chemical in forming the Benzol Products Company. It was a logical alliance. Solvay produced the raw material from its coke ovens. Barrett had considerable experience with refining operations and apparatus, having at the time a small plant making aniline oil and toluidine. General Chemical was included as a producer of sulfuric and nitric acids, large quantities of which were required in the proposed operations. The Benzol Products Company took over the old nitration plant of Barrett at Frankford. This was rebuilt by an Englishman named A. B. Mitchell, son of the principal partner of W. G. Barnes & Company, chemical merchants in London representing Cassella and others that later went into the I. G. Farbenindustrie. Mitchell entirely rebuilt the plant, and with technicians supplied by General Chemical and Barrett, revamped the processes. Aniline oil and nitrobenzene were manufactured,[14] and by the time the war broke out, Benzol Products had demonstrated it could produce high-quality products economically.*

Our pitifully small demand for coal-tar crudes was evidenced by total imports of less than a million-dollars value annually. Coal-tar crudes had entered duty-free until the Underwood Tariff (1913), when "for revenue only," the Democratic Congress placed an ad valorem duty of 5 per cent on benzene, toluene, xylene, naphthalene, with phenol, anthracene, and cresol still on the free list. But the true state of our coal-tar chemical industry was revealed in the cold figures of our imports of the derivatives—dyes, aromatics, medicines—which annually totaled over $10,000,000 in value.[15] It has been estimated the value of these coal-tar products doubled and sometimes trebled by the time they reached American consumers.

Then came the European war and the picture changed as if a hurricane had swept across the landscape. The neglected coal-tar products were suddenly in clamorous demand. Benzene for synthesis into phenol to be converted into picric acid, and toluene to be nitrated to TNT, were prime munitions for the British, French, and Russians. Naphthalene and anthracene were "must materials" in our frantic efforts to establish a coal-tar chemical industry. The nice steady call for sulfate

---

* "If I can modestly say so, we put the fear of God into the Germans as we actually made both nitrobenzene and aniline oil. The Swiss chemical companies, to whom we offered to export these, immediately put out samples in their laboratory as standards which the German suppliers (Badische) had to agree to meet in quality or the Swiss would buy from us. This, of course, was lese majesty to the Germans as they liked to give the impression to the world that they were the only quality makers of anything. Their retort to our quality was to improve their own and cut the price about 2¢ per pound." (J. R. M. Klotz, to author, Jan. 29, 1943.)

of ammonia became a panicky appeal for help from fertilizer and munitions makers.

The first impact of the war stunned our coke producers and tar refiners. They fumbled about, uncertain whether to expand or to wait the coming peace. The steel companies were the first to recover. With a flourish Carnegie and Maryland announced [16] new by-product plants. This was only the speeding up of an expansion undertaken before the war, but by the turn of the year, most leading steel producers—notably United States Steel, Lackawanna, Maryland, and Republic [17]—were rushing installation of equipment to recover light oils from which to separate benzene and toluene. Under the impetus of the war, there was a great demand for new ovens and by-product recovery plants, so that between 1915 and 1921 nearly 4,000 coke ovens of the Koppers type alone, were built. At the same time the vertical-flued oven was introduced in the gas industry, plants being built at Kearny and Camden, New Jersey, St. Louis, St. Paul, and Providence. During this six-year period the output of by-product coke increased nearly sixteen million tons per year.[18] Munitions orders were flooding the country, sweeping the price of benzene from 40¢ to $1.25 a gallon; toluene to $4.00 a gallon; phenol to $1.20 a pound; naphthalene from 2½¢ to 10¢ a pound.[19] These fabulous prices touched off the wildest explosion of chemical activity this country had ever seen.[20]

The combination of greater output and fancy prices shoved up the value of coal-tar crudes from $997,000 in 1914 to $7,340,000 in 1915. These astonishing figures were to be capped in 1916 by a value greater than $30,000,000.[21] This last figure indicated real progress for, during 1916, expanded supply began to catch up somewhat with the exorbitant demand, and prices began definitely to decline. By the end of that year benzene was selling for 60¢ a gallon, pure toluene for $2.50 a gallon, and phenol for 65¢ a pound.[22]

During 1915 fifteen more plants, making a total of thirty, were equipped with benzol-recovery apparatus and that year over 16,600,000 gallons of benzol products were marketed.[23] Only a third of the recovery plants had the opportunity or time to wring two gallons of light oil from a ton of coal: * several secured less than a gallon.[24] The new

* "This, I believe, is misleading. All the by-product plants built after the beginning of the war were of the finest type of construction. I believe most of them are still in operation with much of the original equipment. I recollect that at least one of the plants I visited at that time had white tile walls in the distilling room. While they were built in record time, they were thoroughly modern at that time. With regard to yield, I think you have misinterpreted the paragraph in *Mineral Resources*, the fact being that one reason for the relatively low yield of 1.54 gal. per ton of coal, which is stated in that reference as against the ultimate anticipation of 2½ gal., resulted largely from the fact that all of the gas was not fully stripped of these aromatic hydrocarbons. It was only later that gas requirements for public utilities were changed,

by-product coke plant at Farrell, Pennsylvania, so cheerfully announced by the Carnegie Steel Company just after the war broke out, was an unusual example of unexpected difficulties. The contract had been let to Carl Still & Company, and when these good Germans realized that the benzene and toluene to be produced would make ammunition for the Allies, they instituted a studied campaign of sabotage till in the end, to get the plant finished and operating at all, the steel company had to dismiss the contractors and finish the job itself.[25]

In the early stages the greatest demands were from the British and French Governments for phenol, toluene, and refined naphthalene. Exorbitant prices promoted extraordinary efforts to increase the supply of benzene to be synthesized to phenol, and to work up other sources of toluene.

Prior to the war we had imported phenol for medicines, disinfectants, and the new plastics. Accordingly, when England placed an embargo on this essential material, we were unable to supply even our modest peacetime needs, to say nothing of the new war demands.* Barrett moved quickly to increase production.[26] Since the phenol content of tar is but 0.7 per cent and practice was then recovering only about 0.25 per cent, natural phenol supplies were plainly inadequate and recourse must be had to synthetic phenol from the familiar sulfonation of benzene.

One of the first to suffer from the dearth of phenol was Thomas A. Edison. He needed large supplies for his phonograph records and with characteristic energy he adopted the benzene synthesis. By the fall of 1914 he was furnishing his own needs. This meritorious accomplishment was exploited for much more than it was worth by the daily press, for chemicals had become news and Edison was a name with which to conjure. So the great inventor was sharply criticized [27] for countenancing this wild publicity and for claiming, at least by implication, that this well-known process was his own invention. He paid for this super-publicity by becoming innocently involved in what became known as "the phenol scandal."

Early in 1915, the newspapers carried the story that Edison had bought the Cambria Steel Company's output of light oil and was building a refining plant at Silver Lake, New Jersey, with a daily capacity of 18,000 gallons of benzene to be converted into phenol.[28] Here was a sizable supply which a little group of Germans plotted to keep out of

which fact you cite later, and then all the gas was fully stripped. Experience has led to the much higher recoveries now made, but there are factors such as the cycle of coking time which affects these yields. In the tremendous war pressure, coal is coked at a minimum cycle and this is bound to affect the yields of light oil." (David W. Jayne, to author, Nov. 17, 1942.)

* For phenol production and imports, see Appendix XXIII.

HARRY W. JAYNE

WILLIAM H. CHILDS

JOHN R. M. KLOTZ

EDWARD J. BARBER

Allied munitions plants. Edison turned the marketing of his surplus over to the American Oil & Supply Company, well-known chemical jobbers of Newark, New Jersey, and almost the next day they sold it on contract to the "Chemical Exchange Association." The price was high, and as this buyer was an unknown firm, it put up $100,000 in cash, advance payment. The phenol was delivered to the Heyden Chemical Works, American branch of Chemische Fabrik von Heyden. For every pound of phenol received Heyden returned a pound of salicylic acid which Chemical Exchange in turn sold to Bayer Company, American subsidiary of the great German firm which controlled the patents and trade name on aspirin (acetylsalicylic acid).* All this was roundabout, but speculative juggling was rife in the chemical market and nothing on the surface aroused suspicion.

Shortly after this deal was completed, Dr. Hugo Schweitzer, chief chemist of Bayer Company, and his good friend, Richard Kny, active head of Kny-Scheerer Company, important manufacturers of surgical instruments, gave a dinner at the Hotel Astor in honor of Dr. Albert, financial advisor of the German Embassy in Washington. It was an hilariously happy celebration. The hosts were the partners of the dummy company known as the Chemical Exchange Association. They had good reason to be grateful to Dr. Albert, who had not only worked out the devious details of this chemical coup, but had also provided the $100,000 cash. They had good reason to celebrate, too, for their net profit on the deal was $816,000. Also they were converting large quantities of phenol into a harmless medicinal chemical.[29]

But Edison was not the only producer of phenol. By the middle of 1916, he had many rivals, big and little, producing natural and synthetic material.† Combined, they required an increased production of pure benzene which reached the astonishing total of 21,079,500 gallons in 1916 [30] and 40,387,929 gallons in 1917. In the latter year their output of phenol, natural and synthetic, was 64,146,499 pounds.[31]

Among the many phenol producers of the war period, a couple stand out. The Schlesinger interests controlling the Milwaukee Coke & Gas Company, under the active managership of John W. Schaeffer, built a phenol plant on a farm they purchased near Carrollville, Wisconsin.

---

* See Vol. III, Chap. 21.

† Semet-Solvay Co., Barrett Co., Butterworth-Judson Corp., Dow Chemical Co., Aetna Explosives Co., Newport Co., New England Mfg. Co., Monsanto Chemical Works, United Gas Improvement Co., National Synthetic Co., U. S. Standard Chemical Works, British-American Chemical Co., Bayer Co., Stillwell Chemical Co., Carbolite Chemical Co., Pittsburgh Coal Products Co., General Coal Products Co., Neidich Process Co., Curtis & Hardy, and the Middlesex Chemical Co. (See *Weekly Drug Mkts.* 3, June 28, 1916.)

This operation, which was under John R. M. Klotz,* achieved an output of 135 tons daily. Just before the Armistice, the coke plant was revamped and Koppers ovens installed, while enlargement of the phenol production was planned. Most of the Newport phenol went to J. P. Morgan & Company for shipment to the Allies, and the French Purchasing Commission adopted the product of this plant as the standard upon which its specifications were based.[32]

To increase the supply of toluene, various syntheses were attempted. Cymene from spruce turpentine, a waste product of the sulfite paper mills, when treated with anhydrous aluminum chloride in the presence of benzene, according to the well-known Friedel-Crafts reaction, produces toluene and cumol. The latter can be oxidized directly to benzoic acid, an additional saving of the toluene commonly used to make this useful acid. Like hundreds of chemical proposals of those days, perfectly feasible on paper, this project came to nothing for lack of raw materials. The sulfite mills were not interested in recovering the turpentine,[33] and cheap anhydrous aluminum chloride was to come later with its use in petroleum refining and the production of synthetic anthraquinone.

Another toluene process enthusiastically publicized in its laboratory stage failed on a commercial scale. In this respect it, too, was typical of many organic chemical projects of the war period. Dr. Walter Rittman of the Bureau of Mines proposed to pass the vapors of high-boiling petroleum distillates through metallic tubes at a temperature of 500° to 575° C. and a pressure of 250 to 300 pounds per square inch to produce benzene and toluene.[34] Approved by government officials, a contract was made with the Aetna Explosives Company to work the process commercially. After a year's trial, the Company threw up the project. Yields were so scanty that costs were prohibitive, and furthermore, it was impossible to remove traces of paraffin hydrocarbons retained as impurities.[35]

After we became active combatants, the necessity for more coal-tar crudes—especially more toluene—was intensified. Fortunately the recovery of the coke by-products had come a long way since 1914. Technique had made as great advances as production. By 1918, coke-oven operators turned out 87,562,094 gallons of light oil, 96 per cent of which they separated on the spot as benzene, toluene, solvent naphtha, and xylene. In addition, there came from the coke ovens that year 16,088,000 pounds of naphthalene.[36] One step farther in coal-tar products utilization, we produced 106,794,277 pounds of phenol,[37] most of

---

* Formerly with Barrett and after the war engaged as a consultant, Klotz, who was trained at U. Pa., was later associated with Standard Oil (N. J.) and played an important part in the commercial development of petroleum chemicals.

it immediately nitrated to picric acid. Most of this picric acid was in turn made according to French Government specifications and sold to the United States Government, which delivered it to the French in payment for our heavy purchases of guns and ammunition for the A.E.F.[38] The measure of this progress was double-checked by the acid test of dollars, for while total output of coal-tar crudes increased some 25 per cent during 1917, total value declined $1,500,000.[39]

Behind these cold figures were gigantic labors, and now one more supreme effort was called for. The needs of our Army for TNT, piled on top of British requirements, created in 1917-18 an extra, unbalanced demand for toluene.

Our Army and Navy had accumulated no stock of this modern munition, nor arranged any assured supply of its essential ingredient. Even after the declaration of war, at the first meeting of the General Munitions Board, professional representatives of both armed services had listened listlessly to Leland Summers' warnings of an impending shortage of toluene. Within a couple of months, however, they were crying frantically for TNT; sending experts to the recovery plants to squeeze the last drop out of the benzene fractions; begging the gas companies to rob the kitchen stove and parlor lighting jets by stripping this priceless ingredient; * experimenting with new ideas to crack toluene out of petroleum.

To eke out supplies quickly, the best expedient was to strip city gas. Contracts were accordingly made with the utilities in New York and Brooklyn, Boston, New Haven, Albany, Utica, Elizabeth, Washington, Detroit, St. Louis, New Orleans, Denver, and Seattle, and the good citizens of these cities unwittingly "did their bit" by getting less heat and light. In New York City, due to the stripping of toluene, the heating value of city gas was reduced 6 per cent and the candle power lowered from 22 to 16. Plants to carry out this program began building late in November 1917, and the first units were in successful operation the following April. Not only did the apparatus have to be made, but a skilled operating staff was trained, a notable accomplishment, well worth the cost of approximately $7,500,000.[40] At Standard Oil of Indiana, Thomas Cooke did an outstanding piece of chemical engineer-

---

* "As a matter of fact, the removal of toluene rather improved the light, for removal of the vapors of these heavy liquids made the gas lighter and less inclined to smoke and clog the burners. The early source of toluene was the condensate or 'drip' pumped from the gas mains. There was quite a volume of this in the days when gas companies were delivering a gas which would show a high candle power when burned in an open flame burner. The toluene and other constituents existed in the gas as vapors rather than as true gases, and condensed out as the gas cooled: toluene, benzene, and other constituents were separated by distillation." (John M. Morehead, to author, Feb. 15, 1944.)

ing work in extracting toluene. His accomplishment was conspicuously successful among the war-developed processes.[41]

Planning ahead, the Ordnance Department encouraged enormous expansion of by-product coke ovens to come into production during 1919 and 1920. Seven companies agreed to build eight plants with a yearly toluene capacity of 18,869,401 pounds to be sold to the Government on contracts assuring a return on the initial investment of some $30,000,000. Similar arrangements, calling for the private expenditure of $14,700,000 for five additional plants for 1920, were concluded with four other companies.*

Had the war continued, however, even this enormous coke-oven expansion would have been inadequate. The Army's constantly mounting requirements for toluene could eventually have been provided only from our lush supplies of petroleum. This was clearly foreseen and strenuous efforts were made to rush three possible processes to completion. The Rittman process was given another trial in an experimental plant on Neville Island near Pittsburgh. It was completed at the time of the Armistice but never performed successfully. A similar method, cracking solvent naphtha under high pressure, known as the Hall process, was more successfully operated on a small scale during 1918 at the Standard Oil plant in Bayonne, New Jersey.[42]

The third, most rewarding effort was made by the General Petroleum Company on the West Coast. By a cracking treatment, it secured a commercial yield of 6 per cent of toluene from petroleum distillates, and two large plants at Los Angeles and San Francisco were built at an approximate cost of $5,000,000. Since these installations had a monthly capacity of 3,000,000 pounds of toluene, they promised to answer conclusively the shortage problem, but with the signing of the Armistice, they were never called upon to fulfill this promise.[43]

In early 1918, however, the toluene shortage had been acute. J. M. Morehead,† engineer with the Union Carbide & Carbon Corporation, came to Washington to help Summers with this problem. He became chief of the Industrial Gases & Gas Products Section of the Chemicals Division, and Ira C. Darling, president of Bartholomay & Darling of Chicago, became his assistant and shortly afterwards chief of the Creosote Section.[44] With the cooperation of the Fuel and Railroad Admin-

---

* For a list of the 11 companies and their estimated production, see Appendix XX.

† Morehead also served the War Ind. Bd. as sec'y of the Explosives Div. and member of the Ammonia Committee and was later Ambassador to Sweden (1930-33). He was graduated from North Carolina U. (B.S., 1891; LL.D., 1926) and his career was closely associated with the development of the Union Carbide interests. He holds many patents, especially on electric furnaces, and is the author of *Analysis of Industrial Gases* (1905). He is the only foreigner ever to be awarded the gold medal of the Kungl Svenska Vetenskopsakademien.

istrations, the coke ovens were given coal priorities on a par with the railways and steamships, and on February 26, 1918, nonmilitary uses of toluene were rigidly restricted by commandeering orders to 93 producers and refiners.[45]

An agreement between the producers and the War Industries Board fixed the price at $1.50 per gallon in tank cars for all material released for nonmilitary purposes.[46] Only 5 per cent of the output was so allocated. The manufacture of saccharin was severely curtailed, and production of benzoic acid, certain dyes, and duotone brown ink for rotogravure printing was handicapped, but by midsummer of 1918 the situation improved and continued to do so until, in October, it became doubtful whether nitrating capacity could keep pace with the growing toluene supply. About 100,000 gallons were therefore released for nonmilitary uses during November, and the twentieth of that month, the commandeering order was canceled. At this time the yearly rate of toluene production was 22,000,000 gallons and 11,000,000 gallons had been shipped to our Allies.[47] November 11, 1918, stocks in the hands of producers and nitraters, or in the course of shipment, were some 4,000,000 gallons, a three years' supply for peacetime uses.[48]

Some pressure was taken off toluene by substitution of trinitroxylene for TNT for hand grenades by the Navy Ordnance Bureau, which advanced $3,900,000 for a special plant at the Barksdale, Wisconsin, explosives plant of du Pont. Projected capacity was 30,000,000 pounds of TNX a year, and arrangements were made with Barrett for pure xylene, a hundred or more producers supplying Barrett with the crude material for purification. Work at Barksdale started in March 1918, and by October a part of this operation had come into production.[49]

The Army also wanted to eke out toluene, and during the summer of 1917 sought out a company to make tetranitroaniline. This admittedly tricky, dangerous nitration had never been attempted here. While TNA promised real relief for the munitions pressure—it involved the use of neither toluene nor caustic soda—no prospective makers were anxious to take on this job. As one of the largest producers of aniline, the Calco Chemical Company with a new plant at Bound Brook, New Jersey, was nominated for this task, and its president, Robert C. Jeffcott, agreed as a patriotic duty to produce this substitute explosive. The entire process had to be researched. Apparatus had to be designed and secured. New separate buildings had to be erected. But the work pushed vigorously twenty-four hours a day, and the first batch of TNA came through up to specifications and expected capacities within eleven months. The plant was immediately shut down on the signing of the Armistice.[50]

When the war ended, the dictatorial demand for coal-tar crudes collapsed like a burst balloon and the most optimistic chemical man could not dream where the enormous surplus capacity might be placed. By-product benzene output had jumped from a prewar 2,516,000 gallons to 44,805,000; toluene from 623,000 gallons to 8,861,000; naphthalene from 196,000 pounds to over 16,000,000.* Recovery plants now exceeded the capacity of the beehive ovens. The cry of insistent demand changed overnight to a wail of oversupply.

By-product ammonia was on the same uncomfortable spot. Total production in terms of net tons of sulfate equivalent had been shoved up from 186,749 in 1914 to 378,328 in 1918. These figures include ammonia from gasworks; that only from by-product ovens was 143,249 in 1914 and 348,654 in 1918.[51] The use of sulfate for fertilizer had grown like Jack's beanstalk, but nobody dared hope that normal needs in plant food and for refrigeration could absorb the increased output. In the wild wartime markets, quotations of sulfate had moved up to $7.80 per 100 pounds in July 1918, when the War Industries Board fixed the price at $4.50, or half again higher than prewar. At the same time, anhydrous ammonia prices were set at 30¢ a pound and aqua ammonia at 8¼¢.[52] At the request of the Food Administration, Herf & Frerichs of St. Louis doubled their capacity for liquid ammonia. Frerichs† was asked to duplicate the St. Louis plant at eight different points scattered throughout the country.[53] A proclamation of the President, January 3, 1918, created an Inter-Department Committee ‡ to control the manufacture of ammonia, its importation, storage, and distribution, under direction of the Food Administrator.[54] This control was effective only over the primary producers from coke ovens, gas plants, and even the synthetic-nitrogen operations, so that dealers' prices continued to run riot. During July, these second hands advanced prices 200 to 300 per cent, and fourteen producers of ammonia signed an open appeal to the trade to suppress such unpatriotic profiteers. Among the signers were Barrett, General Chemical, Grasselli, Armour, and Morris.[55]

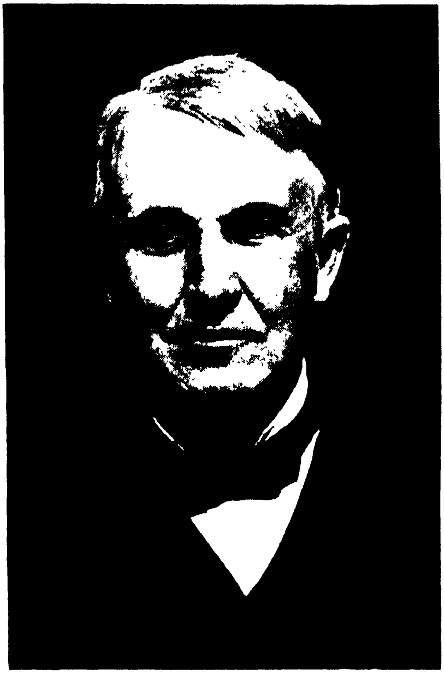
After the war the unexpected happened. During 1919 and 1920

---

* These are 1915 figures compared with 1918. As shown in Appendix XXII, the bulk of the naphthelene produced in the U. S. in 1918 was made by firms not primarily engaged in the operation of coke-oven plants and gas houses.

† Frederick W. Frerichs was born in Germany and educated at Göttingen where, after receiving his Ph.D., he was asst. to Wöhler, 1874-79. Coming to America in 1880, he was for six years with Mallinckrodt, when he resigned to go into the liquid ammonia business in St. Louis. He was a charter member of the Am. Inst. Chem. Engrs., pres., 1911, and treas., 1912-26.

‡ Charles W. Merrill, Food Admin.; L. L. Summers, War Ind. Bd.; M. L. Wilkinson and C. L. Alsberg, Dept. Agr.; Maj. C. S. Backus, Col. W. H. Walker, and Maj. M. J. Whitson, Army; Adm. Ralph Earle, Navy; Maj. J. T. Crabbs, Interior Dept. (See *Drug Chem. Mkts.* 12, Jan. 23, 1918.)



Chemical & Metallurgical Engineering

THOMAS A. EDISON

IRA C. DARLING

Chemical Industries

FREDERICK W. FRERICHS

HUGO SCHWEITZER

strikes in the steel industry, coal mines, and railroads, so curtailed supplies that an actual shortage of both ammonia and sulfate was created. Demand here held up unexpectedly, and similar labor unrest in England so cut its available exportable surplus that an export demand appeared here, which overtaxed our output.[56]

The cleanup of the war surplus of coal-tar crudes was even more startling. Initially it was assisted by the coal strikes, which took up some slack, but out of these cheap, war-surplus stocks, we created new industries that within a few years were to consume far more basic coal-tar materials than the artificial wartime requirements. This transition from war to peace forced many chemical and industrial readjustments.

Toluene never reached a fraction of the munitions need. It did, however, find a steady, growing use as a solvent and in coal-tar intermediates synthesis. Accordingly, this ingredient and xylene, too, were commonly left in the benzene fraction. As a solvent for lacquers, rubber, artificial leather, etc., as well as in chemical manufacturing, a market developed for from 10,000,000 to 12,000,000 gallons of this benzol, but ten times that quantity [57] was soon being poured into the gasoline tanks of the motor fuel blenders.*

The plight of the phenol producers seemed desperate. They had a capacity of more than 100,000,000 pounds a year and the Government held a stock of 35,000,000 pounds.[58] From $1.00 a pound the price tobogganed to 25¢ and by 1919 it had slid down to 8¢ a pound. Synthetic-phenol plants built during the war were being scrapped right and left. Tar distillers were recovering just as little as possible. To help stabilize a critical position, the Government did not advertise its surplus phenol for sale to the highest bidder, but placed it with one of the largest producers, the Monsanto Chemical Works, to be disposed of in an orderly fashion. This surplus was not to be exported, the foreign market being reserved for current output, and the domestic price was fixed at 12¢ a pound. Phenol seemed to be in a stalemate that promised to last five or six years. Yet within three years several synthetic plants had started up again; a big new plant had been built by the Bakelite Corporation; a new synthetic process had been perfected and put into operation by the Dow Chemical Company. The

---

* "I think few people realize the amount of work done to pave the way for this outlet. At times when benzol was in tremendously heavy demand at high prices, and when the petroleum companies were swamped with their own production problems, it was not easy to arouse too much interest in blending benzol with gasoline at the unknown future date when the war would be over. I have always considered that one of the most effective moves which we made in the Barrett Company was the arranging during the height of the war production program for motor fuel outlets which would take care of the new benzol production after the war was over." (Edward J. Barber, to author, Jan. 19, 1943.)

phenol-formaldehyde plastics had found their first great industrial market, and the vast war stocks of phenol vanished in phenolic plastics, molded into radio parts, automobile distributor heads, hundreds of thousands of electrical connections and gadgets.

So certain were the coal-tar distillers that naphthalene was grossly overproduced, that in 1919 they cut their output to 20,114,000 pounds. They, too, guessed wrong. Our infant dye industry found an unexpected export market and this need for naphthalene gobbled up the seeming surplus. In 1919 and 1920 a shortage developed and with it came sharp increases in prices.[59] This stimulated an overproduction and again prices slumped. Naphthalene had ceased to be "only a mothball" and had become a raw material for the production of coal-tar intermediates.

During the war anthracene was the cross-eyed stepchild of the crudes family. It had no important munitions use. Its recovery was not only rather difficult, but it also meant spoiling the pitch residue for roofing or road building. The anthracene fraction distills between 270° and 400° C. If the distillation is stopped at 270°, a soft pitch is obtained; if carried on to 400° C., the residue is hard and brittle. Abroad, the hard pitch found a ready market in fuel briquets, since little tar was used for road making and European recovery practice found it profitable to remove the anthracene. In the United States, conditions were quite the opposite. The call from our textile industries for fast vat dyes produced from anthracene overcame this economic obstacle.* In 1918 Barrett exhibited at the Chemical Exposition in New York samples of American-made anthracene,[60] and by 1920 five producers had turned out 711,258 pounds of 100% refined product and four, 2,829,500 pounds of crude.[61]

Thus upon the foundation of our war-born, coal-tar crudes, we built our new synthetic organic chemical industry.† Excess benzol blended in motor fuels was the germ of anti-knock compounds and high-octane gasoline. More than that, from the war-surplus stocks of phenol came the cheap phenolic resin, forerunner of the entire plastics industry,

* "The United States today still does not produce any appreciable amount of anthracene, for our dyestuffs industry went over to producing anthraquinone from phthalic anhydride for vat colors. While several of us started anthracene separation during and after the war, I think it is rather to our discredit that these operations did not stick in the face of postwar situations with cheap anthracene available for import, and later by the substitution of the phthalic anhydride route to these vat dyes." (David W. Jayne, to author, Nov. 17, 1942.)

† "I have always tried to point out that before the last war this country did have a coal-tar industry, but not a coal-tar *chemical* industry. This is a distinction which is real, even though many people have failed to appreciate it." (David W. Jayne, to author, Nov. 17, 1942.)

demonstrating the principle of modern chemical engineering that if you give chemical producers sufficient quantities of a chemical material at a sufficiently low price, they will sooner or later find a good use for it.*

REFERENCES

1. *Min. Res. 1918,* II, 1445.
2. D. W. Jayne, *J. Soc. Chem. Ind. 33,* 1178 (1914); C. C. Tutwiler, *J. Frank. Inst. 178;* 383-415 (1914).
3. W. E. Hartman, *Iron Trade Rev. 52,* 799 (1913); C. A. Meissner, *Iron Age 91,* 1365 (1913); Jayne, *J. Ind. Eng. Chem. 6,* 952 (1914).
4. L. H. Baekeland, *Gas Age 38,* 134 (1916); *Am. Gas J. 115,* 140 (1921).
5. For review of these early installations, see *Min. Res. 1912,* II, 209; *1913,* II, 455.
6. C. J. Ramsburg, to author, Jan. 5, 1943; *Fortune* 67 (Apr. 1937).
7. Curtis, *Fixed Nitrogen,* p. 72.
8. *Min. Res. 1913,* II, 479.
9. *Ibid. 1914,* II, 408.
10. F. W. Sperr, Jr., *Met. Chem. Eng. 16,* 135 (1917).
11. Jayne, *J. Soc. Chem. Ind. op. cit.*
12. F. E. Dodge, *Trans. Am. Inst. Chem. Engrs. 11,* 120 (1918).
13. H. W. Jordan, *ibid. 8,* 209 (1915).
14. *Drug Chem. Mkts.* 15 (Apr. 24, 1918); Jayne, *J. Soc. Chem. Ind. op. cit.*
15. *Min. Res. 1912,* II, 264.
16. *J. Ind. Eng. Chem. 6,* 783 (1914).
17. *O.P.D. Reptr.* 27 (Mar. 15, 1915).
18. Ramsburg, *op. cit.*
19. Mar. 1915 quotations, *O.P.D. Reptr.;* see also Appendix II.
20. Bur. Mines, *Tech. Paper No. 89* (1915), 19 p.; *Sci. Am. Suppl.* 86 (Aug. 7, 1915).
21. *Min. Res. 1917,* II, 1198.
22. Dec. 1916 quotations, *O.P.D. Reptr.*
23. *Min. Res. 1915,* II, 516.
24. *Ibid.* 546.
25. *Weekly Drug Mkts.* 10 (June 30, 1915).
26. *Ibid.* 9 (Oct. 14, 1914).
27. A. H. Ney, *Chem. Met. Eng. 13,* 686 (1915).
28. *Weekly Drug Mkts.* 5 (Feb. 3, 1915).
29. Alien Property Custodian, *Ann. Rept. 1918-19,* 43.
30. *Min. Res. 1917,* II, 1198.
31. Tariff Comm., *Census of Dyes and Coal-Tar Chemicals, 1917,* p. 12.
32. J. R. M. Klotz, to author, Jan. 29, 1943.
33. *J. Ind. Eng. Chem. 10,* 174 (1918).
34. Rittman, C. B. Dutton, and E. W. Dean, Bur. Mines, *Bull. No. 114* (1916), 268 p.; *O.P.D. Reptr.* 11 (Mar. 8, 1915). In former, an annotated bibliography on the recovery of benzene, toluene, and related products from coal distillation, pp. 215-55.
35. *O.P.D. Reptr.* 48H (May 7, 1917).
36. *Min. Res. 1918,* II, 1520.
37. Tariff Comm., *Census of Dyes . . . 1918,* p. 32.
38. Crowell, *America's Munitions, 1917-18,* pp. 108, 116.
39. *Min. Res. 1917,* II, 1199.
40. For process and operation, see Tutwiler, *op. cit.;* D. Florentine, *Gas Age 38,* 329 (1916); H. C. Applebee, *Gas Age 40,* 151 (1917). For summary of accomplishments, see H. C. Porter, *Gas Age 43,* 521 (1919); *Am. Gas J. 115,* 140 (1921).
41. Klotz, *op. cit.*
42. Hall, *J. Inst. Petr. Tech.* 1, 147 (1915); Dunstan, *Science of Petroleum,* III, p. 2084.
43. Crowell, *op. cit.* p. 106.
44. Baruch, *American Industry in War,* p. 194; Clarkson, *Industrial America in World War,* p. 414.
45. War Ind. Bd., Final Rept. of Chairman, Feb. 1919, p. 413.
46. Garrett, *Government Control Over Prices,* p. 349.
47. *Chem. Met. Eng. 47,* 535 (1940).
48. War Ind. Bd., Final Rept., *op. cit.* p. 415.
49. *Navy Ordnance Activities. World War, 1917-18,* p. 94.
50. Haynes, *Dyes Made in America.*

---

* For two current discussions of the industry, see S. R. Bellamy, *Chem. Age (N. Y.) 28,* 254, and H. G. Sidebottom, *ibid.* 311.

51. Nitrate Div. (Ordnance), *Report on Fixation and Utilization of Nitrogen,* 1922, p. 29.
52. War Ind. Bd., *Price Bull. No. 47,* 7; *No. 48,* 10, 17; *No. 56,* 23. See also Appendix II.
53. *Met. Chem. Eng. 17,* 684 (1917).
54. *J. Ind. Eng. Chem. 10,* 160 (1918); *O.P.D. Reptr.* 26 (Jan. 21, 1918).
55. *Drug Chem. Mkts.* 7 (July 24, 1918).
56. *Ibid.* 25 (Oct. 29, 1919); *Chem. Met. Eng. 23,* 212 (1920).
57. Haynes, *Chemical Economics,* p. 216.
58. Tariff Comm., *Census of Dyes . . . 1922,* p. 19; J. M. Weiss, *Chem. Ind. 46,* 689 (1940).
59. *Min. Res. 1922,* II, 196.
60. *Met. Chem. Eng. 19,* 389 (1918).
61. Tariff Comm., *Census of Dyes . . . 1920,* pp. 21, 25.

Chapter 13

THE POTASH FAMINE

GERMAN POTASH SYNDICATE DICTATES TERMS TO U. S. FERTILIZER INDUSTRY AND LAW OF 1910 PROMPTS SEARCH FOR AMERICAN POTASH SOURCES—SEARLES AND OTHER BRINE LAKES INVESTIGATED—RECOVERY FROM CEMENT FLUE DUST—ALUNITE DEPOSIT FOUND IN UTAH.

SINCE LORD PALMERSTON, in 1840, sent the British Navy to break the sulfur monopoly set up by King Ferdinand of Sicily, no chemical crisis so involved international diplomacy as did the German Potash Law of 1910. Both incidents arose from desperate efforts to bolster a God-given natural monopoly by man-made measures, striking evidence of the powerful antimonopoly forces at work in an economic system of free competition.

The German Law was a brazen attempt to make effective the voluntary Potash Syndicate and to halt the successful attack of American buyers against its controlled prices. To accomplish these ends, it put the German potash mines under control of the State and imposed an export tax that more than equalized the difference between the official cartel quotation and the lower figures at which American buyers had contracted to buy from independent potash producers.[1] This clever cancellation of the favorable prices American fertilizer firms had secured from the independents, called forth the protests of our State Department and there was talk of revoking Germany's "most favored nation" status under our tariff for discrimination against American buyers.

The effects of this highhanded, thoroughly nationalistic act set the stage for the potash situation of World War I. In the United States it had called into being a new, big fertilizer combination, the International Agricultural Corporation; it banded smaller companies into the Independent Fertilizer Manufacturers' Association, a glorified industrial buying club; it promoted the farmers' cooperative organizations; it drove home to fertilizer men, farmers, and government officials the menace of our dependence upon this German monopoly—four results destined to write much chemical history. The legally enforced Syndicate was able, in the period between 1910 and 1914, to consolidate the badly disrupted German potash industry so that it presented a united front to the world.

The scare of the 1910 crisis set our Geological Survey and Department of Agriculture to work seeking every possible American source of potash. Their findings, though useful in the days of the potash famine, were not sufficiently impressive to encourage anyone to resist the swift return of the German monopoly. Within a couple of years it regained domination of our potash market, and at prices ranging from 84 to 91 per cent above the contracts signed with German insurgents in 1909.[2] In 1913, 99 per cent of our imports of 255,101 short tons of fertilizer potash salts, expressed in K_2O, the standard basis of computing potash-bearing materials for statistics and prices, came from the German Syndicate, which in this imperfect world was just about complete control over our potash supplies. The actual imports amounted to 1,053,684 short tons, exclusive of 38,904 tons of potash salts intended for the chemical industry.[3]

In the forced settlement of the old contracts invalidated by the Law of 1910, discounts for quantity and cash had been continued. These terms favored the big buyer and encouraged pooled orders. The agreement of May 1911 set quantity discounts at 13½ per cent on concentrated salts and 14 per cent on crude salts, for 20,000 tons or more of K_2O, with a sliding scale of from 3 to 10½ per cent on quantities from 1,000 to 15,000 tons. The uniform cash discount was 1½ per cent. The so-called "Big Five"—American Agricultural Chemical Company, Armour Fertilizer Works, International Agricultural Corporation, Virginia-Carolina Chemical Company, and Wilson & Toomer Fertilizer Company—all made maximum quantity contracts direct with the Syndicate. Among them they imported most of our fertilizer potash, for all of them had subcontracts with other manufacturers or else resold in the open market at the Syndicate's announced price schedule. In 1914, Wilson & Toomer had 46 such subcontracts; International, 18; Armour, two, and in addition to its own potash requirements, filled those of F. S. Royster Guano Company.

Sales to the smaller fertilizer companies and cooperative associations were made direct by the German Kali Works, the Syndicate's own agency, which was originally incorporated in New York State in 1909, for education and publicity purposes. It was the policy of the New York sales office of the German Syndicate to sell exclusively to fertilizer mixers. There was one exception to this rule, when Kali's American manager, Dr. Henry Huston, became annoyed at the mixers' refusal to increase the K_2O content of their fertilizer above the conventional 2 per cent. To bring them to terms, a campaign was launched for direct sale to farmers for home mixing, the ancient bugbear of the fertilizer industry. He was forced to withdraw this campaign by his infuriated customers, with some minor concessions, which was the last attempt made in this direction.[4] Kali regularly handled sales to the chemical companies with which it had ten direct contracts.[5] This nicely organized marketing system was blasted to bits by the war.

Though at the time the Germans were savagely criticized for the embargo they declared on January 29, 1915,[6] our potash famine was not caused primarily by them. One must never forget that the German State had long held a thoroughly national conception of domestic natural resources, colonies, industries, even of education and research, and that the idea of the State's power and prosperity as something transcending individual welfare or corporate profit was generally accepted by the German people under Kaiser Wilhelm II, as under the Nazi regime. The Potash Law of 1910 exemplified this, and the wartime strategy of their potash and dye monopolies was the result of these ideas.

The Reich used these two chemical weapons differently: first, to prod us into helping Germany dodge the British blockade, and later to deter us from entering the war. German potash mines were producing far in excess of their domestic requirements—in 1913, 46 per cent of the output was exported—and sales abroad would be useful in establishing gold credits. Their coal-tar chemical industry was also accustomed to manufacture for export—prewar some 60 per cent of the dyes and medicinals was shipped to foreign consumers—but in this case the crudes and intermediates that went into the exportable surplus were needed for Germany's own munitions and medicines. It followed logically that potash should be used as a bribe and coal-tar chemicals as a threat.

During the latter half of 1914, therefore, extraordinary efforts were made to ship us potash. As a result, despite severe dislocation of shipping from August forward, 1914 imports were 207,089 short tons of K_2O,[7] off only some 25 per cent from normal. What were feared to be last deliveries reached Baltimore late in August: 550 tons on the *Bohemia* and 400 tons on the *Oosterdijke*.[8] Nevertheless, throughout the autumn, potash shipments through Holland were landed at New York in American ships, the *Matanzas*, the *Massapequa*, the *American Sun*.[9] Difficulties were experienced in getting goods through the blockade, and the American representative of the German Syndicate, Henry A. Huston,* proposed that in order to stop delays, American buyers pay in advance. The potash, if it fell into British hands, would then

---

* Huston had been prof. agr. chem. at Purdue and chief of the Indiana Exp. Sta. before joining the German Kali Works, as St. Louis mgr., in 1903. After being in charge of the Chicago and Baltimore offices, he was moved to N.Y.C. in 1912 and remained as dir. till 1924, when he retired to become a private consultant. He was pres. of the Assoc. Off. Agr. Chem. (1895) and in 1931 Purdue honored him with a D.Sc.

be clearly American-owned. For obvious reasons this smart solution did not appeal to most * American fertilizer manufacturers.[10] Later Huston's assistant, August Vogel, made a cheerful, comforting statement which no doubt reflected the Syndicate's views:

> Potash is not contraband of war and none of the nations at war object to its movement in neutral ships. There is, however, great difficulty in securing railway and river facilities to move it from the mines and storehouses to the coast. The mines are in good condition and enough workmen . . . are available to keep them in operation. . . . There is, therefore, no reason why farmers should not secure some potash in their goods, although the usual 5 to 10 per cent may not be obtained.[11]

Then suddenly the Germans slapped an embargo on all potash shipments. Fear and anger harried them into taking this drastic step. British Orders in Council had declared all foodstuffs contraband and the Admiralty ordered the fleet to tighten the blockade. Germany retaliated by cutting off all the world from the one essential raw material it controlled. From an unexpected source came a revelation of the Teutonic point of view. Wilhelm Ostwald, Nobel prize winner in chemistry (1909), blurted out, "It is in Germany's power to dictate which of the nations shall have plenty of food and which shall starve. Germany is in the position, often realized by Bismarck, to handle the long arm of the lever." [12]

Beneath the boasting and threatening so unseemly from the lips of a truly distinguished scientist was the menacing idea of ruthless State power that Hitler was later so terribly to capitalize.† During 1915, however, the Germans attempted to use the potash lever diplomatically. The Syndicate, which feared to be buried under great piles of surplus salts accumulating at their mineheads, suggested to the German Government that the embargo be lifted for potash rendered unsuitable for

---

* "It may not have been smart but it turned out to be wise, for the Armour Fertilizer Works, coppering the prevailing judgment, purchased a substantial tonnage of muriate under these conditions, and it not only permitted them to supply some of their most urgent fertilizer needs, but also enabled them to sell a substantial tonnage at around $400 to $500 a ton. If I remember correctly, the muriate cost us $70 a ton. All cargoes arrived safely, the last one turning up in Charleston, S. C." (C. H. MacDowell, to author, Nov. 23, 1942.)

† "The eminent Dr. Ostwald was not much of a prophet. The shoe turned out to be on the other foot. The shutting off of phosphate rock imports as well as sulfur-bearing materials brought about by the Allied blockade, had much to do with the breakdown of German agriculture. Malnutrition in plants, farm animals, and humans through phosphorus starvation was one of the major causes of the breakdown in German health and morale. . . . In March of 1919, while in Paris, I secured from the Germans a list of the most needed raw materials to resume limited production. Topping the list was 1,800,000 tons of fertilizer materials (which meant phosphate rock), followed by 250,000 tons of pyrites and 10,000 tons of sulfur." (C. H. MacDowell, to author, Nov. 23, 1942.)

munitions manufacture. The "denaturing formula" was never revealed, but the idea did not appeal to Wilhelmstrasse which was endeavoring to negotiate any sort of a deal to exchange through the British blockade German potash for American cotton.[13] Time and again, from several different approaches, Germany showed her willingness, even her anxiety, to ship us potash. But the British remained adamant. Potash was fertilizer, they said, but cotton could be nitrated to explosives.

Our potash imports,* therefore, virtually stopped. During 1915, only 48,867 short tons of K_2O arrived here. Most of it was from Germany, shipped before the embargo or picked up from German supplies stored in neutral countries. During the next three years fewer than 8,000 tons were imported annually, about a third coming in the form of argols, cream of tartar, and Rochelle salt.[14] During these famine years odds and ends of potash-bearing materials were scraped together from the ends of the earth, even from Africa and Asia, and shipped to the United States. Russia was the largest contributor, furnishing in 1917 and 1918 roughly a fifth of all our imports. The greatest single importation from Russia came from the Czar's Government. It consisted of 4,000 tons of potassium carbonate. It was shipped in 1917, but the boat was libeled by the Revolutionary Government on its arrival, so that although the shipment was offered for $3,000,000, there were no takers, because buyers feared legal complications. Later it had to be broken up and sold in small lots.[15] Japan, Chile, England, Italy, and Spain all made small but regular additions to our scanty stocks which during the war came from 20 to 25 different countries.

Potash prices † reacted immediately and violently to the scarcity, soaring upon the declaration of the German embargo and throughout the war remaining proportionately higher than any other chemical material. At the outbreak of the war, for example, the fertilizer grade of muriate, containing 80 to 85% K_2O, sold in New York for $39.07 a ton. A year later, July 1, 1915, it was quoted at $230 and the January following, at $475, while during 1916 it mounted to over $500 a ton.[16] Crude potassium carbonate, used largely in the chemical industries, which had sold prewar for 3½¢ a pound, rose to 20¢ by the middle of 1915 and to 50¢ by the end of that year.[17] For several months, early in 1916, potassium chlorate, for which there was a munitions demand, was entirely off the American market.[18]

During these famine times current quotations in the tradepress were little more than indicators, actual sales prices being reached by bargain. It was later determined that from the beginning of the war until the Armistice, potash sales were made all the way from $80 to $600 a ton,

---

* For 1913-22 figures, see Appendix XXIV.

† Appendix XXV lists potash prices, 1913-22.

the bulk of them, however, being below $400.[19] There was but one sharp break in the high level of potash prices. It came in 1916, following the arrival in New York, from Vladivostok, of nearly a thousand tons of remarkably pure carbonate estimated to be sufficient for our chemical, dye, and soap industries for two years. It sold briskly at 90¢ a pound. This shipment was in reality a revival, under the stimulus of high prices, of the old pot-ashes trade. It had been leached out of the ashes of sunflower plants, grown extensively in southern Russia for seed and oil, which yielded a fine, white carbonate of 96 to 98% purity.[20]

Though over 80 per cent of the potash imported had always gone into fertilizers, it was the chemical users who first complained of the shortage. Indeed leading fertilizer men declared it quite possible for them to dispense with potash for two or three years. This was something more than whistling by the graveyard, for leading agriculturists declared temporary lack of this plant food, while it would reduce the cotton and truck crops somewhat, would not be nearly so damaging to yields or to the soil itself as would a dearth of nitrogen.[21] Then there was no accepted method of determining the availability of potash in the soil and only totals of potash salts present were known. It is now known that the potash in available form is only a fraction of the total.

On the other hand, the shortage of potassium cyanide threatened a revolution in Mexico. To prevent throwing thousands out of work, Great Britain and the United States agreed to release enough of this chemical to avoid closing the gold mines. Our own chemical industries and the makers of soap, glass, matches, and photographic supplies were the first to feel the lack of potassium salts. Quite generally they substituted the corresponding sodium compounds. The pharmaceutical houses did this in many preparations, and so successfully, that they later defended some of these changes on therapeutic grounds.[22] In the glass industry the forced switch to sodium proved a blessing in disguise.[23]

As time went on, therefore, users of potash as a chemical readjusted or substituted. Moreover, they were helped out greatly by the potassium carbonate from Russia. For potash as plant food, however, there was no substitute. Accordingly, for the fertilizer industry the potash famine became progressively more serious. The Committee on Fertilizers of the Chemical Alliance * made an estimate of the industry's minimum requirements as "218,899 tons of K_2O if available at a price not more than $50 per ton for material containing 80% KCl." In view of the actual quantities available and prices paid, this was little more

---

* See Appendix XII.

than the wishful expression of an ideal. A group of state Agriculture Experiment Station directors were more reasonable when, admitting this quantity would be too low for good agronomy, they set the figure at 150,000 tons of K_2O.[24] The total imports of potash salts for 1916 and 1917 were 1,726 and 504 short tons of K_2O, respectively.

There was but one hope of making good this woeful deficiency. Some American source of potash must be developed. Nullification of the American purchase contracts by the German Law of 1910 had written this warning on the wall in blazing letters and our Government had taken the hint. That very year the Geological Survey and the Bureau of Soils began an active collaboration to explore all possible—and some impossible—domestic sources supported by two appropriations for $40,000 and $12,500 voted by Congress on March 4, 1911.[25]

Within the next two years the potash in Searles Lake, the Bonneville Basin, the Salduro Marsh, the Nebraska lakes, and a score of other brines and surface deposits, the leucite rocks of Wyoming, the greensands of New Jersey had all been prospected and assayed. The kelp beds of the Pacific Coast and the potash wastes of industry had been investigated and appraised. In scores of Bulletins, Surveys, and Reports, these government searches had all been recorded.* In 1915 this spadework was to prove very useful.

All of this advance work was not on paper, nor was it all done by the Federal Government. Early in 1912, clear indications of the great potash beds of the Permian Sea area underlying West Texas and New Mexico were found by J. A. Udden, in brine from a deep boring at Spur, Dickens County. The town was developed in 1909 by E. P. Swenson, later one of the organizers of the Freeport Sulphur Company.[26] Udden, who was director of the Bureau of Economic Geology, University of Texas, followed this significant discovery by identifying appreciable potash in brines from eight other counties in the Panhandle region: Potter, Randall, Midland, Dawson, Ward, Loving, Glasscock, and Borden.[27] In 1916, the Geological Survey decided to investigate whether these brines really indicated substantial subterranean strata of potash or salt strata with commercial concentrations of potash. A test well was bored at Cliffside, Potter County. Results

---

* Dec. 18, 1911, Pres. Taft transmitted to Congress a report which next year appeared as Sen. Doc. 190 (62:2), entitled "Fertilizer Resources of the U. S.," under the joint authorship of F. K. Cameron, R. B. Moore, E. E. Free, J. W. Turrentine, W. H. Waggaman, J. G. Smith, A. R. Merz, R. F. Gardner, C. C. Darwin, C. L. Alsberg, W. A. Setchell, G. B. Rigg, F. M. MacFarland, W. C. Crandall, and E. C. Johnston. This Doc. marked the start of the whole potash research program and was directly responsible for the West Coast kelp activities. It was the "potash bible" of that day. See also the annotated foreign bibliography on potash (to 1928) by J. F. T. Berliner, Bur. Mines, *Bull. No. 327* (1930), 578 p.

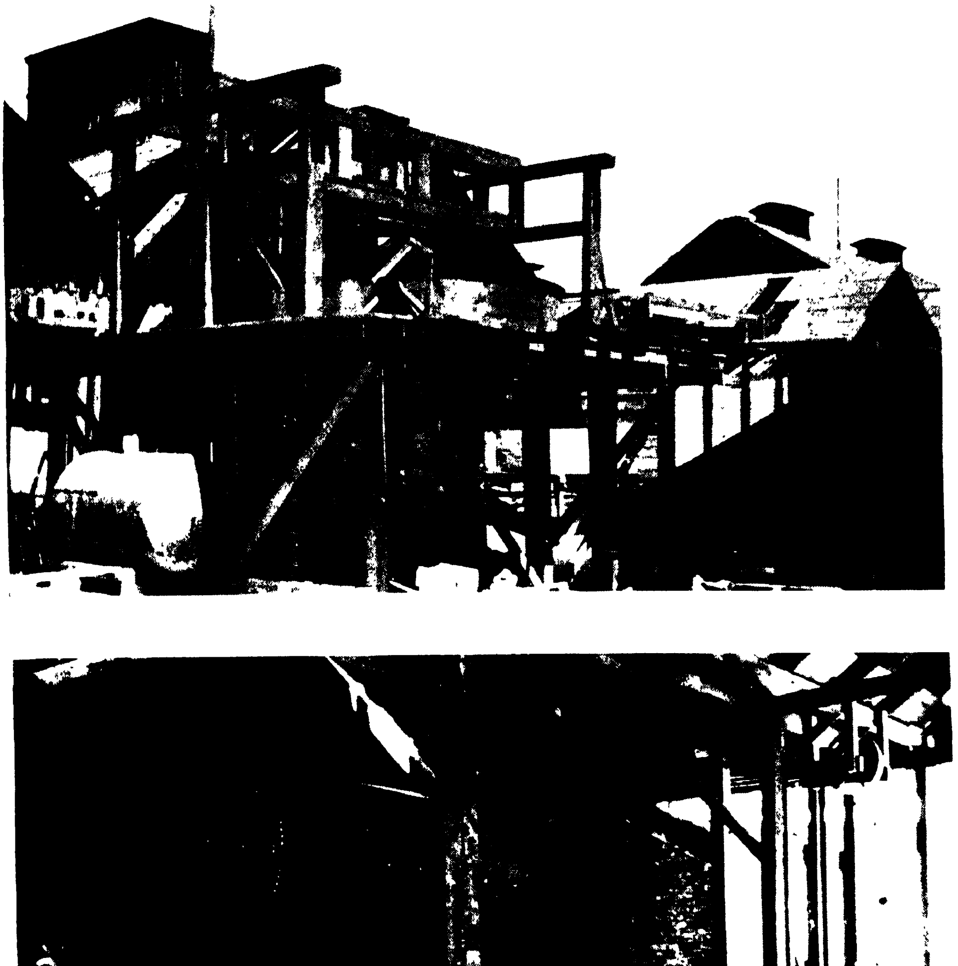
were negligible, and thereafter observations were made at many oil wells drilled in the section. Brines were analyzed showing 23% of potash. More significant was the actual recovery of crystals of potash salts, polyhalite ($K_2SO_4 \cdot MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$) and sylvinite (a mixture of KCl and rock salt).

All this was exciting but unsatisfactory, for little reliance could be placed in these samples. The churn of rotary drills so mixed the material recovered that it was not safe to speculate as to the extent of strata, unless it was very thick. The chance of "salting" lower beds by materials from higher levels was great, and "hangover bailings" could be very misleading. Finally, the different solubilities of the various salts injected additional uncertainties as to the representative character of brines in the drilling water. The war had ended before these Permian beds, now the basis of our domestic potash industry, were more than "important, if true."

The hope of finding just such subterranean deposits as the Stassfurt beds was the brightest will-o'-the-wisp of those earlier explorers. Up in Nebraska and Nevada, favorable indications were reported [28] in 1913, but two years previous the Railroad Valley Company had spent $115,000 in a series of test drillings in Nye County, Nevada, that only proved the project was not even a good gamble.[29]

Nevertheless, the presence of appreciable quantities of potash salts in brine lakes and surface deposits in California and Nevada had been so thoroughly authenticated by the Geological Survey's mineral scouting parties, that three great tracts of desert basin land–133,928 acres–were withdrawn from 160-acre placer claims by the President: Columbus Marsh, Nevada, was approved January 16, 1913; Searles Lake and Panamint Valley, California, Febrary 21, 1913. The laudable purpose was to put potash mining on a stable legal base. The Department of the Interior sought from Congress a general leasing law under which potash deposits already reserved or found hereafter on the public domain might be developed, but got instead a commission to study a revision of all our mineral land laws.[30] Not till October 2, 1917, was the Potash Leasing Law enacted.[31] It permitted potash prospecting on government lands. The first potash exploration license was issued by Secretary of Interior Lane on February 2, 1918, and covered 2,560 acres of alkali marsh in Inyo County, California. Throughout the war, vigorous prospecting continued in Texas,[32] Oregon,[33] Colorado,[34] and other states.

Two potash projects were actually under way in the United States when the war broke out. They were quite different: the one from lake brines, the other recovery from kelp. Both were curiously prophetic of what were to become our most important wartime sources.



Filter tank and intermediate bin (*upper*), and furnace end of column (*lower*), California Trona Co. Borax Plant, May 1909.

First exploited in 1873 for its borax content, Searles Lake had eventually passed into control of the California Trona Company, formed with a capital of $1,000,000, by C. E. Dolbear and seven others. The original financing was inadequate, so the Company negotiated a loan from a Foreign Mines Development Company, an affiliate of the English-controlled Consolidated Gold Fields of South Africa, Ltd. The reorganized Trona purchased the plant and mining rights of the dormant Bernardino Borax Company, but ran into operating troubles and was unable to repay the loan. Thrown into bankruptcy in 1909, 90 per cent of the common stock was bought in by Guy Wilkinson, American manager of the Gold Fields interests, and S. W. Austin was appointed receiver. He kept the property alive, even fighting off an invading organized band of forty claim-jumpers led by engineers and supported by gunmen. Austin, who was Register of the Land Office in this district, continued his connection with the Searles Lake development, later becoming manager of the Los Angeles office, of the American Potash & Chemical Corporation, eventual successor to the receivership.[35]

Potash had been noted in the Searles Lake brines as early as 1898 by Whitman Symmes, a mining engineer who at the time was in charge of the local plant of the California Borax Company. He surveyed and analyzed the whole Lake area and tried without success to interest his employers in exploiting the property for potash and soda, as well as borax. The potash agitation of 1910 revived interest in these forgotten ideas, and under the Austin regime, C. E. Dolbear, F. S. Pearson, and the Solvay Process Company all sampled and analyzed the Lake brine. The prospect of potash now gave an additional incentive to press the conflicting land claims, and the Government entered the dispute by sending Dr. E. E. Free of the Bureau of Soils and H. S. Gale of the Geological Survey to investigate. Accompanied by Wilkinson, they took six samples on March 6, 1912. These were analyzed at the Mackey School of Mines, Reno, and the Geological Survey Laboratories at Portland, Oregon, and the results published for the first time. The average composition was: sodium chloride, 51.6%; sodium sulfate, 19.22%; sodium carbonate and bicarbonate, 12.79%; sodium borate, 3.37%; potassium chloride, 12.07%; and sodium arsenate, 0.17%.* Dolbear protested that eight months previously he had written a report displaying full knowledge of the potash content and that this information had leaked from his office. He claimed to have received acknowledgment of priority from the Geological Survey whose report had

---

* A more recent typical analysis gives the following: Na, 33.57%; K, 6.06; Cl, 37.02; SO_4, 12.96; CO_3, 6.7; B_4O_7, 3. Combined: NaCl, 43; KCl, 13; Na_2SO_4, 20; $Na_2B_4O_7$, 4.3; Na_2CO_3, 13. (See Turrentine, *Potash*, p. 76. Teeple also gives a complete analysis in his *Industrial Development of Searles Lake Brines*, p. 18.)

maintained that previous analyses had ignored the element potassium or reckoned it as sodium.[36]

A new flock of speculators took claims on unowned portions of the Lake and then sat tight waiting for someone to buy them out. When the Government set aside the whole of the area as a potash reserve, the California Trona Company held claims to some 26,000 acres. Victor Barndt, president of the Railroad Valley Company, protested these claims and urged a new allocation under a federal leasing system.[37] California Trona dropped less advantageous claims one by one,[38] till in 1918 the Government patented to it clear title to 3,320 acres. The remaining 16,000 acres were immediately leased to eight or ten different interests, none of which ever produced any potash.

In June 1913 the California Trona Company was taken over completely by the American Trona Corporation, organized with a capitalization of $12,500,000 for this purpose. The incorporators were J. A. Brown, Richard Bennett, Jr., and William K. Dupre, Jr.,[39] and most of the money was found by the Gold Fields group. American capitalists, who had a minority interest, refused to take a larger share "mainly owing to the apparently antagonistic attitude of the Government at Washington." [40] The plan was to produce potash by the Hornsey process of carbonating the brine to remove the sodium carbonate as bicarbonate, which was filtered and calcined to soda ash. The filtrate was then successively evaporated, filtered, and crystallized to recover the potash, borax, and sodium sulfate, possible because of their different solubilities.[41]

A four-year contract was entered into with the Pacific Coast Borax Company, giving each the minor product of the other: American Trona to sell Pacific Coast all borax it produced and to get all soda made by the other party to this sensible alliance. At this time Pacific Coast owned 2,240 acres in Searles Lake, purchased years before from the old Searles-Smith borax interests.[42] The soda ash produced by American Trona was to be exported to the Orient from West Coast ports. Potash (in the form of the chloride) was to be sold to Southwest markets in quantities which it was not anticipated would draw the fire of the German cartel. Commercially, this was a well thought-out program. It tripped up technically. The new plant was completed in 1914, but its trial run was a discouraging failure. The separation of the salts, which worked like a watch in the laboratory, did not work at all in the plant, so that commercial production was not achieved until September 1916.

Potash from kelp, the only other American source actually exploited prewar, was a return to the age-old practice of using seaweed as fertilizer and the primitive chemical operation of making pot-ashes from the same material. It was a pet project of the Department of Agriculture which, in 1912, surveyed the shore from Puget Sound to Cedros Island off southern California. Some 230 square miles of kelp groves were charted and on paper an annual yield of 22,000,000 tons of wet weed, equivalent to a million tons of potassium chloride, was calculated.[43] Abundance of raw material and the chemical possibilities of working up such by-products as iodine, ammonia, acetic acid, glue, sizing materials, and activated carbon, were enticing. Much laboratory work was done and later, in 1916, the Department built an experimental kelp products plant at Summerland, California, with Dr. John W. Turrentine, one of our foremost potash authorities, in charge. Turrentine had been fertilizer resources chemist for the Department of Agriculture since 1911.

For many years farmers had been harvesting this giant seaweed for fertilizer on their own land, but the potash panic of 1910 inspired many attempts to commercialize the product either by burning or by drying and chopping it for direct application to the soil. As early as 1912, two California companies, the Coronado Chemical Company of Cardiff and the Pacific Kelp Mulch Company of Terminal Island, were engaged in this business,[44] and a year later eleven such firms were reported by the Geological Survey.* Among these was one which courageously essayed to employ these long, slimy festoons of seaweed as a chemical raw material. In 1914 the American Potash Company built a plant at Long Beach, California, designed to recover iodine and potassium salts and to treat the residue to produce cellulose pulp.

In the hunt for domestic sources, inspired by the German-American controversy of 1910, potash-bearing minerals were not overlooked. Extensive deposits of alunite ($K_2O \cdot 3Al_2O_3 \cdot 4SO_3 \cdot 6H_2O$) with the theoretical composition of 11.4% potassium oxide and 37% alumina, had previously been located in Colorado, Nevada, and Utah. In 1912, two scouts of the Geological Survey, B. S. Butler and H. S. Gale, described a great deposit of exceptional purity at Marysvale, Utah.[45] Prior to the war, C. H. MacDowell (1910), president of the Armour Fertilizer Works, and Howard F. Chappell,† vice-president of the General Chemical Company, being vitally concerned with American potash in-

---

* Ocean Products Co., North Pacific Kelp Potash Co., Pacific Coast Kelp Co., Puget Sound Kelp Potash Co., Aquatic Products Co., Pacific Products Co., all of Seattle; Pacific Kelp Mulch Co., American Potash Co. (successor of the Coronado Co.); Kelp Products Co., San Pedro, Calif.; Kelp Products Co., San Francisco; Mexican Kelp Fertilizer Co., Los Angeles. (See *Min. Res. 1913*, II, 94.)

† Chappell was the son of the Chappell of Moller & Chappell, acid and heavy chemical mfrs. of Chicago, and nephew of Dr. P. S. Chappell of Baltimore. The latter, with William Davison (later Davison Chemical Co.), began the manufacture of superphosphate and mixed fertilizers under patents taken out by Chappell in 1850. The Moller & Chappell plants were in the General Chemical merger and Howard and his brother Harry became officers of the new corporation.

dependence, investigated this deposit and organized the Mineral Products Company to secure mining rights. A plant was completed at Marysvale the middle of September, and on October 20, 1915, the first carload, 28 tons of potassium sulfate, was shipped. Of this shipment, W. C. Phalen said: "This is among the first output of potash from a mineral source in the United States, and so far as is known, it is the first production of potash salts from alunite in the world, as the foreign deposits have been worked primarily for the potash alum and not for the potash salts." [46] The process used, originated by Chappell, himself, crushed the ore to the size of peas and then passed it slowly through rotary kilns at 750° C., after which the roasted alunite was digested with boiling water for several hours; filtered through Kelly presses; the cake (chiefly alumina) stored; and the potassium crystallized from the filtrate in multiple-effect evaporators.[47] This was the only attempt to tap domestic mineral sources of potash dating prior to the stimulus of the German embargo.* In fact, throughout 1915, when it produced 1,518 short tons of K_2O, this Mineral Products project was the only one to register any actual output.†

That thousands of tons of potash were being ignored in the waste dust of American cement mills was pointed out by W. F. Hillebrand of the Geological Survey in 1904. That any profitable use of this bothersome waste would be advantageous was readily admitted by the industry. Some hit-and-miss experimenting had been done, but no simple, economical method evolved till 1912. At a meeting of the American Institute of Mining & Metallurgical Engineers, the chief metallurgist of the Bureau of Mines, Dr. F. G. Cottrell,‡ read a paper on "Dust Precipitation by Electrostatic Means," [48] which set forth the method which under the expert engineering development of Dr. Walter

---

* "Following up laboratory research by Mark Shoelds at Armour on leucite, the Fertilizer Works shipped a carload of this material to Chicago, leased a switch engine for steam and pressure, and in a pressure vessel produced potash close to the yield indicated by the research. As I recall, the ore came from Wyoming and almost alongside a deposit of coal. Transportation facilities would have to be provided, and freight on potash was high, so the matter was not followed up. It was demonstrated however, on a substantial scale, that potash can be recovered from leucite relatively inexpensively. Shoelds also did work on the Cartersville, Ga., shales which contained around 8% of K_2O, and found the potash not difficult to recover." (C. H. MacDowell, to author, Nov. 23, 1942.)

† For a firsthand account of the whole alunite development, see Appendix XXVI.

‡ Cottrell made other distinguished contributions in the separation of gases and to the practical use of patents as endowments for research. He was trained at Calif. (B.S., 1896), Berlin, and Leipzig (Ph.D., 1902). After teaching at his Alma Mater, he went to the Bur. Mines in 1911 as chief physical chem., moving up to dir. (1920-21), thence to fixed-nitrogen work with the Dept. of Agr. till 1930, when he resigned to enter private consulting practice. He was chairman of the Div. of Chemistry of the Nat. Res. Council, 1920-22, and in 1933 chief consulting chem. of the T.V.A. He has been awarded the Perkin, Willard Gibbs, Holly, and other hon. medals.

Chemical & Metallurgical Engineering

F. G. COTTRELL

JOHN E. TEEPLE

CARL L. MODESITT

JOHN H. SHOW

Schmidt of the Western Precipitation Company of Los Angeles made this recovery practical. That same year, the Riverside Portland Cement Company, near Riverside, California, installed the first Cottrell unit and in 1913 added others to cover all its ten kilns.[49] This development had been more or less forced "progress by injunction," as John Teeple once called such compulsory waste recoveries, since the owners of neighboring orange groves had sued the Company on the grounds that dust from its plant was a damage as well as a nuisance. The collected dust was rich in potash and the Company, with poetic justice, sold it as fertilizer to the same orchardists who had sued. Later, the dust was leached and high-grade potash salts recovered by crystallization. Yields were raised by adding small amounts of feldspar and salt to the cement raw materials. In 1915 the Riverside mills were making 504 short tons (K_2O) of material with 20% available potash.[50]

Across the continent at Hagerstown, Maryland, the second Cottrell system was installed by the Security Cement & Lime Company with the deliberate intent of potash recovery. This project just preceded the war and was hurried to completion by the prospect of the potash famine. The first trial run was made June 15, 1915, and three additional units were working by the end of the year. This proved to be a notably successful venture, and publication of its cost data and engineering details[51] encouraged other cement companies to undertake potash recovery, an innovation in the industry which has had permanent effects, and one of the few wartime potash-from-waste projects that has persisted.

Dr. Cottrell's discovery was equally applicable to the recovery of the considerable quantity of potash fed into blast furnaces, and when the Riverside cement experience was reported at an American Chemical Society meeting in Allentown, Pennsylvania, it caught the attention of R. J. Wysor, blast-furnace superintendent of the nearby Bethlehem Steel plant. His investigations were favorable to the idea and Bethlehem was the first in the potash recovery field.[52]

In Europe, potash recovery from sugar-beet refuse, molasses waste, and distillery slop had long been standard practice. Prior to the war such salvage had been neglected in this country, but the techniques were available and so effectively applied, that during the war stress potash from the beet-sugar refineries was second only to recovery from natural brines.

Thus the soundly berated German Potash Law of 1910, by stirring interest in our domestic sources of this essential element, had inspired a thorough survey of possible means of freeing ourselves of this foreign natural monopoly. Our resources from kelp, brines, and minerals had been well prospected. The various promising industrial wastes had been studied. Here and there in all fields tentative starts toward reclaiming potash had been made and quite a store of technical experiences had been accumulated—all of which were to become exceedingly useful in the famine of the war period.

REFERENCES

1. For details, see Stocking, *Potash Industry*, Chaps. 3 and 4; H. R. Tosdal, *Quart. J. Econ. 28*, 140-90 (1913).
2. H. M. Hoar, Bur. For. Dom. Com., *Trade Prom. Ser. No. 33*, 22 (1926).
3. *Min. Res. 1924*, II, 30.
4. J. W. Turrentine, to author, Feb. 2, 1943.
5. Hoar, *op. cit.* p. 20; *Min. Ind. 1912*, 694.
6. *O.P.D. Reptr.* 11 (Feb. 8, 1915).
7. *Min. Res. 1918*, II, 391.
8. *O.P.D. Reptr.* 10 (Aug. 31, 1914).
9. *Weekly Drug Mkts.* 8 (Nov. 4, 1914); 8 (Dec. 16, 1914); 8 (Mar. 3, 1915).
10. *O.P.D. Reptr.* 33 (Nov. 2, 1914).
11. *J. Ind. Eng. Chem.* 7, 76 (1915).
12. Hearings Pub. Lands Comm. on S. 45, June 1917, p. 58.
13. *O.P.D. Reptr.* 11 (Feb. 15, 1915); 11 (May 3, 1915).
14. *Min. Res. 1918*, II, 391.
15. P. G. H. Boswell, *J. Soc. Chem. Ind. 38*, 198R (1919).
16. War Ind. Bd., *Price Bull. No. 47*, 16; *Weekly Drug Mkts.* 15 (Mar. 22, 1916).
17. Tariff Comm., *Tariff Inform. Ser. No. 21*, 161 (1920).
18. War Ind. Bd., *op. cit.*
19. Hoar, *op. cit.* p. 23.
20. Boswell, *op. cit.*
21. *Min. Ind. 1914*, 611; *1915*, 584; W. H. Bowker, *J. Ind. Eng. Chem.* 7, 59 (1915).
22. *Drug. Circ. 58*, 639 (1914); *66*, 508 (1918).
23. *O.P.D. Reptr.* 76B (Dec. 10, 1917); Tariff Comm. *op. cit.* p. 161.
24. A. W. Stockett, *Mfrs. Rec.* 58 (Nov. 14, 1918).
25. G. O. Smith and M. M. Parker, Hearings Ways & Means Comm. on H.R. 4870, June 10-11, 1919, p. 65.
26. Haynes, *Stone That Burns*, p. 134.
27. For early explorations, see G. R. Mansfield, *Ind. Eng. Chem. 15*, 494 (1923); H. W. Hoots, Geol. Surv., *Bull. No. 780B* (1925).
28. *Met. Chem. Eng. 11*, 82 (1913).
29. *Min. Sci. Press 107*, 176 (1913); *Min. Ind. 1913*, 618.
30. *Min. Ind. 1913*, 620; *O.P.D. Reptr.* 27 (Mar. 10, 1913).
31. *Eng. Min. J. 104*, 612 (1917); *Min. Res. 1917*, II, 465.
32. *Drug Chem. Mkts.* 3 (Nov. 17, 1915); *J. Ind. Eng. Chem. 9*, 1152 (1917).
33. *Drug Chem. Mkts.* 8 (Sept. 20, 1916).
34. *Ibid.* 8 (Nov. 14, 1917).
35. For early history of Searles Lake, see Teeple, *Industrial Development of Searles Lake Brines*, Chap. 2; *Min. Res. 1912*, II, 885; *Min. Ind. 1913*, 611; C. E. Dolbear, *Eng. Min. J. 95*, 259 (1913).
36. Dolbear, *Eng. Min. J. op. cit.; Min. Res. 1912*, II, 885.
37. *Eng. Min. J. 101*, 149, 277 (1916).
38. Teeple, *op. cit.* p. 22.
39. *Eng. Min. J. 95*, 1266 (1913).
40. *Min. Ind. 1913*, 614.
41. Teeple, *op. cit.* p. 22.
42. *Min. Res. 1917*, II, 410.
43. F. K. Cameron, Dept. Agr., *Rept. No. 100* (1915).
44. *Min. Res. 1912*, II, 903.
45. B. S. Butler and H. S. Gale, Geol. Surv. *Bull. No. 511* (1913).
46. *Min. Res. 1915*, II, 110.
47. *Ibid. 1916*, II, 117.
48. *Met. Chem. Eng. 10*, 172 (1912); see also Smithsonian Inst., *Ann. Rept. 1913*, 653-85.
49. W. H. Ross, A. R. Merz, and C. R. Wagner, Dept. Agr., *Bull. No. 572* (1917); *Met. Chem. Eng. 10*, 611 (1912).
50. Tariff Comm., *op. cit.* p. 167.
51. *Cement World*, Sept. 1917; A. C. Hewitt, *Eng. News 76*, 1222 (1916).
52. R. J. Wysor, *Bull. Am. Inst. Min. Met. Engrs. 121*, 1-32 (1917); L. Bradley, *J. Ind. Eng. Chem. 10*, 834 (1918); *Iron Age 99*, 199 (1917); *Eng. Min. J. 103*, 176 (1917).

Chapter 14

POTASH FROM ANYTHING AND EVERYWHERE

NATIVE BRINES IN WEST FEVERISHLY WORKED FOR POTASH—NEBRASKA LAKES PRODUCE LARGEST WARTIME TONNAGE; POTASH PRODUCTS, FIRST AND BIGGEST PLANT, FOLDS UP AND OTHERS FOLLOW—SEARLES LAKE RICHEST SINGLE SOURCE; MANY PRODUCERS, BUT ONLY AMERICAN TRONA SURVIVES—POTASH VENTURES IN KELP, ALUNITE, GREENSANDS, CEMENT DUST, ETC.

DURING THE AUTUMN of 1909, a wide-awake senior at the University of Nebraska, working as an assistant in the geology department, was analyzing samples labeled "alkali salts" sent in from the western part of that state. Hundreds of salt lakes dot this region, and being chemically minded, the youthful imagination of Carl L. Modesitt was fired by these bitter waters and their surrounding rims of white salty crusts because of their high potassium content. He conferred with John H. Show, a recent Nebraska graduate. Rumblings of the potash war reached them, and being blissfully ignorant of all the heart-breaking research that had so often failed the world over to find the means of commercially exploiting tempting brine deposits, they convinced themselves that they had solved the American potash problem with a great domestic supply.[1]

Together, Modesitt and Show analyzed all available samples and found from 15 to 33 per cent K_2O content. They determined to explore the brine lake country to determine exactly which were the richest and most promising deposits. In this venture they were joined by Clark C. Denny, Victor I. Jeep, and M. E. Cornelius, all former students of the University of Nebraska. These young enthusiasts left the laboratory and set forth exploring in the sandhills of western Nebraska. On March 21, 1910, after borrowing, begging, otherwise obtaining materials, and supplementing it with their meager savings, Cornelius, Jeep, Show, and Modesitt arrived at Alliance, with camping equipment and supplies, tools and other materials believed necessary for field work. A team and wagon was hired to take them to various lakes for exploration, and that evening camp was set up 13 miles east of Alliance, on the shores of Jesse Lake. It turned cold and rainy and shelter was sought in abandoned sod houses, but nothing could dampen their youthful spirits. The party covered 100 miles and took samples consisting of it was by the Government and commanding unlimited stores of the best, cheapest potash in the world. He added unequivocally that neither the German Government nor the Cartel would brook any competition or hesitate to employ any means to annihilate it.[13]

The Trona officials were not scared off by these hints. Within a year after the war's end, they added borax recovery and by the end of 1919 were turning out 40 to 50 tons daily. During this period the process was again revamped. The so-called, Morse quick-cooling method * to get better separation of potassium chloride and sodium borate was adopted, but better yields, clearer separation, and lower costs were still sought.[14]

During the war another company produced potash at Searles Lake. The Solvay Process Company had a double interest in these brines, as possible competition in soda ash and as a source of potassium salts. Having worked out a process, Solvay joined forces with the Pacific Coast Borax Company in building a $700,000 plant at Borosolvay, for the recovery of potash, soda ash, and borax.[15] This deceptive separation again proved stubborn and the 1917 production was not impressive. By the first of 1918, however, it had been worked up to 200 tons a month.

In both towns—Trona and Borosolvay—the plants operated at maximum capacity throughout 1918, shipping salt running 60-70% KCl and 15% borax.[16] Experimentation continued at both plants after the war, but in 1920 the joint enterprise was abandoned as no longer interesting to its principals. Potash was again in the control of the Germans. New, cheaper sources of borax had been discovered. The recovery of soda ash was not economic. The Borosolvay plant was accordingly shut down and never reopened.[17]

Solvay's interest in Western brines was not confined to Searles Lake. This company had been quietly prospecting many salt deposits and lakes, and it selected as most likely the Salduro Marsh, an area of 125 square miles covered with brine in winter and a 3-foot crust of salt in

---

* "This device was adopted first by the American Trona Corp. at Searles Lake, with elaborations, and was the principal factor that enabled them to break through with a feasible process for separating potassium chloride and borax with the recovery of both in a highly refined state. The Germans saw it in operation there, sent a description to Germany and thence it spread to France, Spain, and Russia. It shifted the world production from an 80% KCl basis to the 96% basis which now characterizes the major output. It was the outstanding improvement in potash processing up to the recent application of the flotation principle, first applied in the Carlsbad area. At Searles Lake it is spoken of as the Turrentine process, but Dr. Mumford in his 1938 article speaks of it as the Morse process. Morse was in charge of the plant at that time and authorized its installation. I am not gunning for personal credit but I should like to have it recorded that our strenuous efforts at Summerland during World War I resulted in permanent good to the potash cause through this improvement in process." (J. W. Turrentine, to author, Feb. 2, 1942.)

summer. Analysis[18] revealed workable quantities of potash in a brine high in chlorides and notably low in sulfates—NaCl, 81.04%; $MgCl_2$, 9.07%; KCl, 7.03%; $CaCl_2$, 0.88%; Na_2SO_4, 1.98%. Commercially, the location was advantageous, being on the Western Pacific Railroad 110 miles west of Great Salt Lake. Here, in the fall of 1916, plant construction began and as usual the first attempts to separate and crystallize the brine constituents were not successful. Abandoning artificial heat methods, a process of solar evaporation was devised, employing a series of circular, concentric canals through which the brine was circulated toward the center over dikes, till a concentration was attained from which the potassium chloride precipitated. The first potash was produced in May 1917, and this operation continued till the Armistice. Solvay thereupon organized a subsidiary, the Utah-Salduro Potash Company, which took over this property, only to be forced by German competition to suspend.[19]

Two other, well-known corporations, Diamond Match and Virginia-Carolina Chemical, ventured into the recovery of potash from natural brines. Both organized operating subsidiaries: the Utah Chemical Company and the Salt Lake Chemical Company. Both selected Great Salt Lake, whose waters contain a little potash (KCl, 3.16%).[20] The Utah project, launched in February 1916, worked up bitterns obtained as a by-product in the solar manufacture of salt by the Inland Crystal Salt Company. The Salt Lake plant started a few months later, working directly on the Lake water. Both plants were active during 1917-18; both closed down when the war emergency ended.

Not far from Searles Lake, to the northwest, is Owens Lake whose heavy brine had excited chemical curiosity even before the war. A process to recover the soda and potash by solar evaporation and fractional crystallation had been invented by Carl Elschner, and the Inyo Development Company, backed by the Stauffer interests of San Francisco, had been formed. A plant was built during the summer of 1915, and under the management of E. B. Davis began producing late in September. Fundamentally this was a sodium carbonate recovery and as such was profitable during the high-price era of the war, but potash was also recovered in small quantities.[21] Late in 1917, Thomas M. Skinner, Jr., was at Owens Lake building another brine-reduction plant,[22] but this started too late and was never completed. Scores of similar small brine operations were undertaken during the war.[23] Some never materialized. Others made unimportant contributions to our potash supplies. All vanished when German material came back into the market.*

---

* The potash content of natural U. S. brines is tabulated in Appendix XXVIII.

As a source of wartime potash, kelp was second to brine, a bad second. Though this industry was established in 1912 and 11 kelp plants were operating in 1914, their number declined to 9 in 1916 and to 8 in 1918. As technique advanced from simple kelp ash to refined salts and other chemical by-products, the competitive pace quickened. Thus this development transcended technically the ignored prophecies of David M. Balch who, in 1905, envisioned kelp's chemical potentialities,* yet commercially it fell far short of the hopes of the official experts.[24]

The earliest company, the Coronado Chemical Company, which began experimenting in 1906 and was in production in 1912, was united with the Pacific Chemical Company to form the American Potash Company in 1914, and at once began a new plant at Long Beach under the management of Leslie H. Thompson.† The next year this operation was taken over by the American Products Company, which in turn shortly became the Lorned Manufacturing Company.[25]

Hailed as the first concern "to make any serious attempt to produce kelp fertilizers,"[26] the Kelp Products Company of Point Loma, California, marketed in 1915 a material containing 15% potash, 2% nitrogen, and 0.5% phosphorus, which had been developed by E. Blanckenberg. Processing costs were disproportionate to the concentration of available plant food ‡ and this attempt failed in 1917. It was repeated more effectively at the San Diego plant of the Swift Fertilizer Company in 1916 and the powdered product shipped to the Company's own Eastern factories.[27] Though a quarter of a million dollars were spent on this plant and much research conducted, joint recovery of potash and ammonia, even by a large fertilizer maker for self-consumption, was not economical. Most of the two-score companies which came into the kelp field during the war and dropped out again with bewildering alacrity, made no such ambitious attempts. They operated a simple process consisting of drying the kelp in direct-fired rotary kilns and burning it to an ash containing roughly 30% potash.

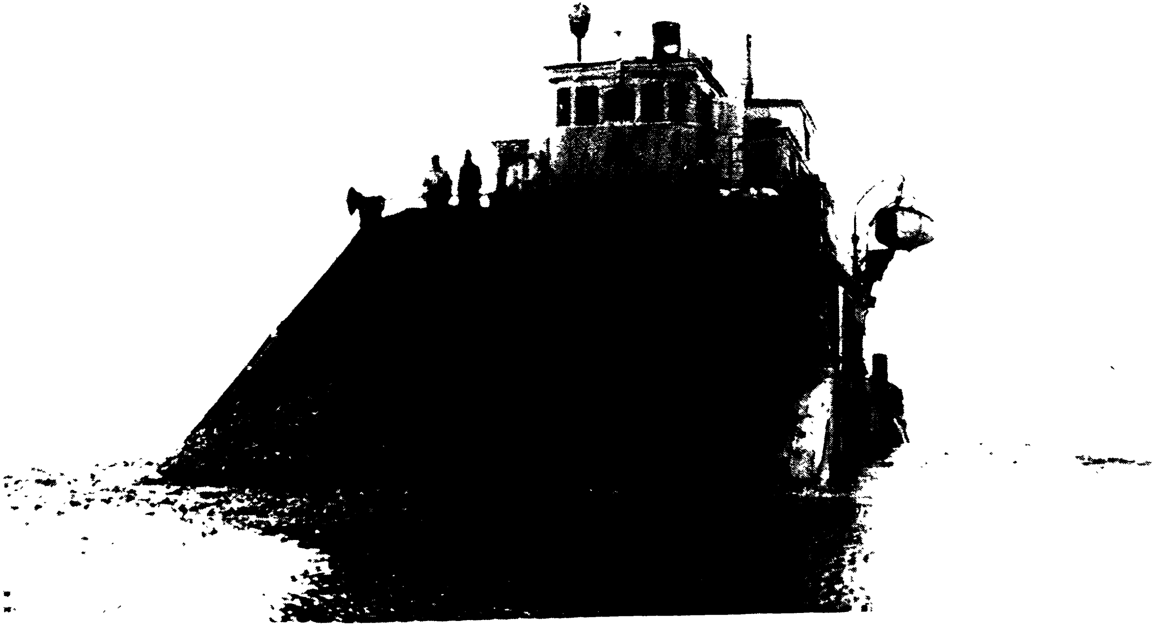
Paradoxically the greatest producer of potash from kelp was a plant designed to produce acetone. This was the operation of the Hercules

---

* Among many articles Balch wrote to popularize kelp, the best is in *J. Ind. Eng. Chem. 1*, 777 (1909).

† "Thompson entered the kelp game at the behest of his friend, George Simmons of St. Louis, who had invested $50,000 in a fanciful enterprise (Coronado Co.) conceived, promoted, and managed by an ex-minister of the Gospel, a very good orator but very weak on chemical engineering. Nail kegs were to be the major product with a beautiful line of other things as by-products, which never materialized. Except in the matter of time this company was not the pioneer of anything." (J. W. Turrentine, to author, Feb. 2, 1943.)

‡ For an analysis of plant-food constituents of kelp, see J. S. Burd, Calif. U., *Exp. Sta. Bull. Nö. 248* (1915).



Kelp harvester of San Diego Plant of the Hercules Powder Co., 1918.

Powder Company on the shore of San Diego Bay, the largest, most interesting and successful of all kelp-products plants.[28] Here, 1,500 tons of kelp were harvested and processed daily in a unique plant costing close to $3,000,000, which turned out 18 tons of potash every twenty-four hours.* The main product, however, was acetone, needed by the explosives company to fulfill its big contracts with the British for cordite. The story, therefore, belongs with our wartime efforts to provide this solvent. Like the kelp project of the Diamond Match Company at Wilmington, California, this Hercules operation was fundamentally chemical in its conception and execution. Both operations were also regarded realistically by the companies as war expediencies. Hercules scrapped its big plant at the close of hostilities. The match company had charged off its $250,000 investment to operating expenses against the output of potassium chloride, 80% grade. This was obtained by leaching kelp ash and evaporating the resulting brine to crystallize out the potassium salt,[29] which was sorely needed to oxidize to the chlorate, an essential ingredient in match-heads.

If the war had continued, potash recovered from various native minerals would have undoubtedly made a greater contribution. Starting late, however, these projects, due to the research and engineering work involved, did not generally get into operation until 1917 or 1918. Except for recovery from cement-flue dust, they could not meet the bitter postwar competition. A number of recovery methods proved feasible, however, and as potash-bearing minerals—alunite, greensands, and feldspar—are abundant in different sections, there is certainly no danger of an ultimate potash famine should more easily worked deposits of potash salts be someday exhausted.

The country's entire production of potash from alunite in 1915 came from the Mineral Products Company and totaled 1,518 short tons of K_2O. This company was reorganized that year as an operating concern under the name of the Mineral Products Corporation. To provide working capital, its backers, C. H. MacDowell and Howard Chappell, took in some friends among the Eastern chemical fraternity. Chappell was president, and MacDowell and S. J. Jennings of the United States Smelting, Refining & Mining Company, vice-presidents; directors

---

* "If special mention is due any one company for kelp-potash development, it should be given the Hercules Powder Co. According to my recollection, potassium chloride as such was produced by only three kelp plants, namely, Hercules, Diamond Match, and the Government's plant, which I operated. Kelp turned out to be a practically complete flop from the viewpoint of permanence, but you might mention one result which still has world-wide application in the potash industry, came near revolutionizing that industry, and which was first developed and applied in the Government kelp plant at Summerland. I refer to the vacuum-cooler crystallizer or quick-cooling process which has supplanted the old vat-cooler crystallizer system in universal use prior thereto." (J. W. Turrentine, to author, Feb. 2, 1942.)

were C. J. Faulkner, Jr., W. H. Gelshenen, Carl F. Hagerdon, Ernest C. Klipstein, and Frederick Leon.[30] During the next year, production was much curtailed by a fire which shut the plant from early November to the end of the year. In 1918, operations were resumed on a greater scale and continued till the end of the war, when the mine and plant were taken over by Armour & Company. When the ammonia market broke badly in 1920-21, the plant was closed and the aluminum nitride which had been made electrolytically was converted to anhydrous aluminum chloride.* A substantial tonnage of potash sulfate had been recovered during the war and sold at a nice profit. The stockholders got back their investment with good dividends, one of the few potash ventures that actually paid out.[31]

By 1917, two other active producers and three prospective producers were in the Marysvale district: Pittsburgh-Utah Potash Company, Utah Potash Company, and the Potash Products Company, while organization had also been announced of the Alunite Company of America to refine, at East St. Louis, ore shipped from Colorado.[32] The Utah Potash Company, formed in 1915 by Los Angeles capitalists with a capital of $1,500,000, announced a new process (Detwiller) for treating alunite with nitric acid to produce potassium nitrate and alumina. In 1917, this company shipped raw alunite to a reduction plant at Trenton, New Jersey, but reported no production of potash that year. Dr. F. K. Cameron resigned from the Bureau of Soils to become its research director.[33] The Florence Mining & Milling Company began to roast alunite in the summer of 1917 and ship the calcined product (16% K_2O) for direct mixing in fertilizers. That same year, the American Smelting & Refining Company produced alum in a plant at Murray, Utah; Swift & Company built a calcining plant for treating alunite at Harvey, Louisiana; the Caraleigh Phosphate & Fertilizer Works of Raleigh, North Carolina, produced calcined alunite at the Marysvale plant of the Florence Company.[34]

Processes to extract potash from common, abundant feldspar (potassium-aluminum silicate) have been as numerous as patents to get gold from seawater—and as successful—and a number of companies † chased this feldspar will-o'-the-wisp, but no production was reported. Georgia sericites and shales, containing sometimes as much as 9% K_2O,[35] were investigated by Armour & Company [36] but not exploited, though in

---

* "The property is now owned by Armour and the alumina tailings are still being sold for copper pigging and electric-furnace refractories." (C. H. MacDowell, to author, Nov. 23, 1942.)

† U. S. Potash Co.; Electric Smelting & Aluminum Co.; Potash & Chemical Products Co.; North American Reduction Co.; International Feldspar Co.; Rush Chemical Co.; and Advance Chemical Co. (See *O.P.D. Reptr.* 11, April. 19, 1915; *Min. Res. 1916,* II, 130, *1917,* II, 439.)

1918 the Georgia Potash & Chemical Company acquired a large slate acreage and Cottrell patents rights for the Southern states.[37] This project was still-born, for hostilities ended before it got under way.

Of the siliceous sources, greensands[38] (glauconite) in New Jersey and leucite in Sweetwater County, Wyoming,[39] were the bases of interesting experiments and development, but actual potash recovery from these sources was only 105 short tons.[40] Three companies only, actually got potash from greensands. The Kaolin Products Corporation started with a pilot plant at Jones Point, New York, producing a ton a day by a process patented by H. W. Charlton.[41] On a large scale, difficulties were encountered and need for additional money forced reorganization in 1917 to the American Potash Company, and in 1918 to the Eastern Potash Corporation. At this stage $300,000 had been spent in perfecting the process. The new corporation, capitalized for $7,500,000, was headed by Waldemar Schmidtmann who, as president of the International Agricultural Corporation, had been a leader in the 1910 fight against the Potash Syndicate. Hardly had this setup been completed, before the war ended.

The Waverly Chemical Company's plant at Camden, New Jersey, produced a little hydrated potassium carbonate under the management of Samuel Peacock. From 1916 to 1919 this salt was sold at 35 to 45¢ a pound (prewar, 3 to 4¢) to the cut-glass industry, but it was frankly a wartime project and was quickly dismantled. Also avowedly opportunist was the potash-from-greensand recovery of the Atlantic Potash Company which first proposed to employ the Eckel process,[42] but switched to the von Kolnitz method.[43] It mined greensand at Marlton, New Jersey, and extracted potassium chloride at a small plant at Stockton, Pennsylvania, but there was no production till 1918 and it lasted but a few months. Other greensand projects were afoot in 1918, but only one came close to realization. F. Tschirner's process of heating greensand with lime and salt was tested in 1917 by the Geological Survey experts at Yorktown, Virginia, and showed 70 to 80% potash recovery. The R. S. Ryan & Company was building a plant for this method near Bedford, New Jersey, when the war ended.[44]

Potash from Wyoming leucite had only one large-scale operation. The process was worked out by Guy Sterling, a mining engineer of Salt Lake City, and depended upon a continuous volatilization principle in which leucite was ground with salt, fused in rotary kilns, and the potash recovered from the fumes in bag collectors. After trial in a test plant, T. W. Boyer, Salt Lake City banker, and other Western capitalists incorporated the Liberty Potash Company with a capital of $11,000,000, and a plant was built at Green River, Wyoming, despite discouraging handicaps. The officers were T. W. Boyer, president;

Guy Sterling, vice-president and general manager; E. M. Allison, Jr., secretary-treasurer.[45] Equipment was hard to get; shipping conditions terrific; labor was locally nonexistent. The first power plant, costing $50,000, was commandeered by the Navy, putting construction back six months, so that operation began just as peace was restored, and initial operating difficulties were never fully conquered.[46]

Potash from cement dust was an outstanding success among the waste-recovery operations. The Riverside Portland Cement Company found it so profitable—1915 potash sales $100,000 and profits $80,000 [47] —that it turned by-product into chief product in 1917 and stored cement clinker, concentrating on potash production.[48] At the other pioneer plant, the Security in Hagerstown, 1917 costs of collecting potash were 47¢ per unit of K_2O minus depreciation and royalty.[49] In 1917, 9 cement companies had embarked on this promising waste recovery, and 1,621 short tons valued at $700,523 were reclaimed; but in 1918, though 4 more cement mills became producers, K_2O output fell to 1,549 tons. When the war ended, 12 potash recovery plants reported production at cement plants and at least 5 more were building or nearing completion.[50]

Next to brine as a source of potash were molasses-distillery waste and Steffens waste water from beet-sugar refineries.* The number of reclaimers from distillery waste increased from 4 in 1917 to 8 in 1918.† Western Industries,[51] which started potash recovery in 1916 and United States Industrial Alcohol, which did not begin till 1917,[52] were the most important of these and both continued to recover this waste after the war. In the beet-sugar industry 5 companies were reworking their waste water for potash in 1917, and 3 more in 1918.‡ Practically all the molasses-beet sugar potash went to the fertilizer makers.

High potash prices revived the old American industry of leaching wood ashes, which once held a high place in international trade, but was ruined by the competition of the German mineral salts. In 1916, chiefly in the hardwood sections of Michigan and Wisconsin, 45 lumber companies reported an output of 412 short tons of K_2O valued at about $270,000.[53] This pot-ashes production grew to 621 tons from 49 firms

---

* For 1915-18 production, see Appendix XXVII.

† Western Industries Co., Agnew, Calif.; Jefferson Distilling & Denaturing Co., Harvey, La.; Puerto Rico Distilling Co., Cerecibo, P. R. Swift & Co., Harvey, La.; Mason By-Products Co., San Francisco; Northern Alcohol Co., Billings, Mont.; Joslin Schmidt Co., Cincinnati; and U. S. Industrial Alcohol Co., New Orleans and Baltimore. (See *Min. Res. 1917*, II, 450; *1918*, II, 412.)

‡ American Beet Sugar Co., Oxnard, Calif.; Poindexter & Co. (no production in 1917); Spreckels Sugar Co., San Francisco; Great Western Sugar Co., Denver; Columbia Sugar Co., Bay City, Mich.; Holland-St. Louis Sugar Co., Decatur, Ill.; Holly Sugar Co., Huntington Beach, Calif.; Larrowe Milling Co., Mason City, Iowa; United Engineering Co., Blissfield, Ind. (See *Min. Res. 1917*, II, 451; *1918*, II, 412.)

the following year, and in 1918 to 673 tons from 51 firms.[54] The ancient technique of leaching the ashes with hot water and then heating the residue to redness was practiced, thus burning off much of the carbon. By the addition of lime, most of the potassium was found in the form of the hydroxide. The old market too was supplied: soap and glassmakers and commercial laundries.

The famine instigated a lot of unorthodox potash recovery schemes from the widest variety of materials. Besides hardwood and sawdust, it was proposed that hay, cactus, water hyacinth, sagebrush, banana stalks, castor pomace, bracken, even tobacco ashes salvaged from the ashtrays, might solve the pressing problem.[55] Water-soluble potash was actually recovered from burned cottonseed hulls by the Phoenix Chemical Works[56] and the Gulf Fertilizer Company,[57] while the Armour Fertilizer Works, in its East St. Louis plant, burned these in a current of air, under the boilers, recovering potash carbonate by the Cottrell method.* Wool washings from the mills in Massachusetts were reworked in the third attempt of the Diamond Match Company to supply itself with potassium chlorate.[58] The Arlington Mills, also at Lawrence, tapped this same source, but results were not great. All the miscellaneous industrial wastes turned out negligible quantities, but any likely chance was eagerly taken: even 100 tons of gunpowder which had been stored away in an Army arsenal since 1875, were reprocessed for the potash content.[59]

REFERENCES

1. Modesitt, to author, Sept. 27, 1943; W. H. Maupin, interview, *Drug Chem. Mkts.* 10 (Nov. 21, 1917); *Min. Ind. 1918*, 587.
2. Modesitt, *op. cit.*
3. Maupin, *op. cit.*
4. H. M. Hoar, Bur. For. Dom. Com., *Trade Prom. Series No. 33*, 82.
5. *O.P.D. Reptr.* 20 (Apr. 24, 1916).
6. F. K. Cameron, *J. Frank. Inst 180,* 641 (1915)
7. H. I. Smith, *Eng. Min. J. 134,* 515 (1933).
8. *Min. Res. 1916*, II, 88; *1917*, II, 409.
9. *Ibid. 1916*, II, 89; *1917*, II, 409; *Min. Ind. 1918*, 590.
10. *O.P.D. Reptr.* 27 (Mar. 3, 1913).
11. Text, *Min. Res. 1917*, II, 465-67.

---

* "The recovery of potash from cottonhull residue was a novel procedure. The delinted cottonseed hulls were ground to secure the short fiber attached to the hulls which was not recovered in gin delinting. This fiber was being used to supplement cotton linters used for nitrating. The hulls were bulky, required much space to store, and presented a serious fire hazard, but contained a small percentage of potash. I suggested that they be burned in a kiln, in suspension, following the technique used in burning powdered coal, and the combustion products passed through a Cottrell precipitator to recover the potash as carbonate. To secure a further credit, waste-heat boilers were to be installed, as oil mills use steam in their cooking. The installation proved successful, and a fair tonnage of potash was secured. Some of this potash was used to produce potassium permanganate in a small manufacturing laboratory operated by the Armour Fertilizer Works. A part of the output was used in the gas-mask cannisters supplied to General Pershing's first 25,000 regulars sent to Europe in 1917." (C. H. MacDowell, to author, Nov. 23, 1942.)

12. *Drug Chem. Mkts.* 12 (Mar. 20, 1918).
13. H. O. Tucker, Hearings Ways & Means Comm. on H.R. 4870, July 14, 1919.
14. R. W. Mumford, *Ind. Eng. Chem. 30,* 872 (1938).
15. *O.P.D. Reptr.* 109 (Oct. 2, 1916); *Drug Chem. Mkts.* 6 (Nov. 1, 1916); *Min. Res. 1917,* II, 412.
16. *Min. Res. 1918,* II, 404.
17. Teeple, *Industrial Development of Searles Lake Brines,* p. 24.
18. Turrentine, *Potash,* p. 70.
19. *Ibid.* p. 69; *Min. Res. 1916,* II, 100; *1917,* II, 413; *1918,* II, 405.
20. *Min. Res. 1916,* II, 413.
21. *Ibid. 1915,* II, 102-3; Elschner, *Min. Sci. Press 112,* 155 (1916).
22. *Drug Chem. Mkts.* 9 (Dec. 19, 1917).
23. *Min. Res. 1917,* II, 414; *1918,* II, 405.
24. Cameron *et al., Fertilizer Resources of U. S.,* Sen. Doc. 190 (62:2), 290 p.
25. L. H. Thompson, *Chem. Met. Eng. 19,* 450 (1918).
26. *Min. Ind. 1914,* 620.
27. Turrentine, *op. cit.* p. 58; *Drug Chem. Mkts.* 10 (Jan. 24, 1917).
28. C. A. Higgins, *Pharm. Era 51,* 333 (1918); *J. Ind. Chem.* 9, 391 (1917); *Met. Chem. Eng. 18,* 576 (1918).
29. Turrentine, *op. cit.* p. 58.
30. *Weekly Drug Mkts.* 16 (Dec. 22, 1915); *Eng. Min. J. 101,* 82 (1916).
31. C. H. MacDowell, to author, Nov. 23, 1942.
32. *Drug Chem. Mkts.* 5 (Aug. 15, 1917).
33. *J. Ind. Eng. Chem.* 7, 1084 (1915).
34. *O.P.D. Reptr.* 22 (Nov. 26, 1917).
35. H. K. Shearer, Ga. Geol. Surv. *Bull. No. 34* (1918); S. W. McCallie, *Eng. Min. J. 104,* 643 (1917); *Drug Chem. Mkts.* 10 (Oct. 3, 1917).
36. MacDowell, *op. cit.*
37. *Min. Res. 1918,* II, 408.
38. G. H. Ashby, Geol. Surv. *Bull. No. 660,* 27-58 (1918).
39. A. R. Schultz and W. Cross, Geol. Surv. *Bull. No. 512* (1912).
40. *Min. Res. 1920,* II, 98.
41. *J. Ind. Eng. Chem. 10,* 6 (1918).
42. U. S. Pat. 1,011,172 (1911).
43. U. S. Pat. 1,201,396 (1916).
44. *Min. Res. 1917,* II, 440; *1918,* II, 408.
45. *Drug Chem. Mkts.* 6 (Jan. 1, 1919).
46. G. D. Parkinson, Hearings on H.R. 4870, *op. cit.,* June 10, 1919, p. 119.
47. *O.P.D. Reptr.* 57 (Aug. 12, 1916).
48. *Ibid.* 52 (May 7, 1917).
49. J. J. Porter, gen. mgr., quoted in *Chem. Engr. 26,* 313 (1918).
50. *Min. Res. 1918,* II, 407, 585.
51. *Weekly Drug Mkts.* 9 (Sept. 30, 1914).
52. *O.P.D. Reptr.* 18 (Sept. 24, 1917).
53. *Min. Res. 1916,* II, 155.
54. *Ibid. 1920,* II, 98.
55. *Drug Chem. Mkts.* 7 (Feb. 14, 1917); 10 (Nov. 21, 1917); 31 (June 19, 1918).
56. *Min. Res. 1917,* II, 456.
57. *O.P.D. Reptr.* 15 (July 3, 1916).
58. *Min. Res. 1916,* II, 163.
59. *Drug Chem. Mkts.* 15 (Sept. 19, 1917).

Chapter 15

THE POTASH DEBACLE

ON ANTICIPATED POTASH IMPORTS, PRICE FALLS BELOW COST—POTASH EMBARGO LIFTED, BUT CONTINUED SHORTAGES HEARTEN AMERICAN PRODUCERS—THEY BAND UNSUCCESSFULLY FOR PROTECTIVE TARIFF—KALI SYNDIKAT MAKES DEAL WITH AMERICAN FERTILIZER COMPANIES—AMERICAN TRONA POINTS WAY TO POTASH INDEPENDENCE.

BY HOOK AND CROOK, from all and sundry domestic sources, we had been able to produce about a fourth of our prewar potash imports. It was a lively adventure. Results seldom balanced the effort demanded. Many of the ventures were pretty small-change gambling; only a few of them paid out. Nevertheless, as a chemical experience, this wartime effort was more than worth the potash it supplied, even at the famine prices.

It was one of our first attempts thoroughly to exploit all the chemical possibilities of a great number of competitive raw materials. The situation was utterly abnormal, but it taught some practical lessons. It demonstrated the ability of American chemists to blaze new trails. It showed that Yankee tinkering can be very useful in chemical engineering. It gave a lot of American businessmen a stiff course in chemical economics. Possibly most important of all, it taught many Americans, particularly many farmers, the importance of chemicals in our daily existence and the advantages of making the nation chemically independent.

The abrupt ending of the war came at a crucial time in the potash situation. The very day of the Armistice, jurisdiction over potash had been shifted from the War Industries Board to the Bureau of Mines, and Dr. Van H. Manning, its director, was instructed to make a thorough survey [1] of domestic sources. The summer before, F. W. Brown, in charge of fertilizer investigations of the Bureau, had toured the 14 potash plants on the Pacific Coast and found recovery costs so high that he was very pessimistic of their ability to compete with Germany.[2] Since late 1917 prices had been declining. Many new operations were coming into production and more were in prospect. Imports from Japan were increasing. There was some talk of a potash surplus in 1918,[3] due to growing supplies and better distribution of available material under the control of the War Industries Board. The boom price of \$5 to \$6 per unit, i.e., 20 pounds, 1/100 of a short ton, of K_2O, had come down to \$4 to \$5 per unit. The expansion of 1917-18 had been made in anticipation of a net return of at least \$4, but the Armistice terms had not been settled before the price broke to \$2.50.

This was actually below the cost of most domestic producers, still buyers and producers, alike, recalled the old German price of 75¢ a unit, and with the prospect of early peace, buyers were not interested in American potash at three times the prewar quotation. Plants everywhere shut down. Many were dismantled and sold for junk. As if to drive a final nail into the coffin of this war-born industry, the chairman of our Shipping Board announced in Paris that a deal had been concluded with the French, who upon restoration of Alsace-Lorraine, again controlled the Alsatian mines, to ship their potash to this country as ballast in the Board's cargo ships.[4] When no French potash [5] appeared, F. K. Cameron of the Bureau of Soils and Hoyt S. Gale of the Geological Survey were sent abroad to investigate.[6]

By the end of February 1919, most of the Nebraska operations had closed. The National Potash Company plant was sold to satisfy creditors and reorganized as the Union Potash Company. Likewise, the William Berg Company was liquidated and reorganized as the Merriman Potash Products Company.[7] Only the Potash Reduction Company seriously planned to continue. In January 1919, it revamped its plant to reduce costs in production and was so successful that savings of 50 per cent were effected.[8] Between September 1919 and October 1920, this operation turned out 25,412 tons of crude salts, equivalent to about 6,000 tons of K_2O. Plans were afoot to add refining operations so as to produce not only caustic potash and carbonate but soda alkalies, when the Treasury Department sued the corporation for \$2,000,000 back excess-profit taxes. The plant was shut down and never reopened.*

Except for the Government experimental plant at Summerland, all the kelp-products factories shut down. The chief object of the \$6,000,000 Hercules Powder operation at San Diego—acetone for cordite—having disappeared, this plant was immediately salvaged.[9] The two Searles

---

* "The issue arose out of the interpretation of expenditures: the Government contended that the expenditures were capital investment; the Company, that they were operating expenditures. While the wrangling continued, the officers of the Company became discouraged, and there seemed to be no incentive for completing the conversion. The property became dormant in Feb. 1921, and a huge fire destroyed nearly all the plant buildings and ruined the equipment. What remained from the devastation was sold for junk. Then, and then only, did the Government abate in full the amount previously levied as a tax assessment. Needless to say, history has proven that the Treasury Department erroneously passed sentence upon an industry that would unquestionably have continued operation and production for some considerable time thereafter." (C. L. Modesitt, to author, Sept. 27, 1943.)

Lake plants remained open, but their operations were curtailed almost to an experimental scale. Armour bought the Mineral Products Corporation outright for $100,000, closed it for overhauling, and reopened it early in the summer.[10] Even the by-product recovery plants—cement, sugar beets, and distillery waste—had little incentive to reclaim potash. By the summer of 1919, American potash was being hawked about at $1.75 to $2 a unit. There were few buyers.*

As yet not a ton of either French or German potash had reached this country. The fertilizer manufacturers suddenly discovered with astonished dismay that for the spring 1920 season they must still depend upon American supplies. They rushed to stock up and the price snapped back to $2.50 a unit. The potash companies scraped their stock bins. In the Nebraska lakes district, for example, they had been left holding some 70,000 tons, which were grabbed up by a horde of eager buyers. Plants that had not been dismantled opened again with contracts in their safes for every pound that could be turned out prior to next spring.[11] Output that year was off 40 per cent from 1918 figures.†

So real was this new scare, that the President, conscious of farmers' needs, suggested to the War Trade Board that the war embargo on potash might very properly be lifted. This was done August 7, 1919, and after that date potash, even if produced in Germany, might be freely imported from anywhere except Hungary and Bolshevik Russia, exceptions then about as serious as a ban on pineapple imports from Iceland. The first shipment came from Alsatian mines, 1,300 tons of kainite and 350 tons of chloride, landed at Baltimore, August 2, 1919.[12] Six weeks later the first contract for German potash since 1914 was concluded—10,000 tons for delivery over the next six months—the cargo space having been arranged through Tarleton Winchester of the Shipping Board.[13]

The Kali Syndikat fell down on deliveries, and as both parties were touchy, the dispute was tart. The Germans could not get even the limited coal assigned to the potash industry and they wanted to barter potash for coal. Since this country was in the throes of the big coal strike, this proposal was not very practical. Meanwhile our fertilizer industry was still short of potash. Total imports during 1919 were only 39,619 tons from Germany and France (some of it transshipped through Holland and Belgium) and from Chile.[14] The Chilean potash came to the du Pont Powder Company from its nitrate works, where since 1917 it had been skillfully recovering potassium salts from the

---

* For good accounts of the Armistice crisis in potash, see W. B. Hicks, *Min. Res. 1918*, II, 401; A. E. Wells, *Chem. Engr.* 27, 259, 283 (1919).

† For detailed figures, see Appendix XXVII.

caliche. In 1919 these Chilean imports reached the sizable total of 16,603 tons.[15]

Having been reconciled to a swift if not painless death, American potash producers, unexpectedly revived by the shortage, dared to hope for a resurrection of their industry. When a measure to control potash imports was introduced into the 66th Congress—the so-called Lane Licensing Bill (S. 5557)—these hopes blossomed. After this bill died of neglect in committee, Thomas W. Boyer, president of the Liberty Potash Company, called together a group of the leaders in Denver to organize active support for a protective tariff. They formed the United States Potash Producers' Association, elected Boyer president, A. C. Harragin of American Trona, vice-president and treasurer, and F. W. Brown, secretary, and resolved not only to work for a tariff bill, but also to conduct an educational campaign among farmers. Taking a leaf from the German propaganda book, they started a bimonthly Bulletin * in the interests of American potash. They mustered a representative membership of 24 firms, and when a new bill was introduced by Joseph W. Fordney, chairman of the House Ways and Means Committee, they rallied to its support.[16]

To safeguard a domestic production of this key raw material, H.R. 4870 proposed to license all potash imports under the Secretary of the Interior, for a period of five years. The price was to be maintained at $2.80 per unit for the first two years, at $2 the next year, and at $1.50 the final two years, ending June 30, 1924. Thereafter, imported potash salts and compounds were to become subject to 10% ad valorem duty. Licensing was to continue, import permits to be issued only for sufficient potash to balance domestic production against consumption, at prices determined by the Secretary of the Interior. These measures would probably have enabled the more efficient of the American producers to survive. At least, so it was believed and so stated at the hearings.

The Bureau of Mines strongly supported this bill. It had been in close touch with the situation since 1910 and was thus able to appraise the potential domestic output expertly and to weigh the necessities of the domestic producers disinterestedly. It released for publication its careful investigation of the whole industry,[17] an exceedingly frank, useful survey which summarized the situation as follows:

> *Nebraska lakes*. Not more than 15 per cent of the lakes contain more than 2% salts in the brine with 25% K_2O; fuel for evaporation and drying, the greatest single cost, must be brought from Wyoming; probably five large plants would reopen if assured $1.75-$2.25 for several years; output

---

* Published irregularly to July 28, 1922.

would be 50,000-60,000 tons, but not a permanent source, and delivered price could never be less than $1.25.

Searles Lake. Brine runs 7.5% potash, estimated to contain as much as 20,000,000 tons;* finished product contains 50% K_2O as chloride and two companies, at Trona and Borosolvay, could make 50,000 tons yearly; despite high freights, may sell in the East at $1 per unit, borax by-product being an important element in reducing costs.

Great Salt Lake and Salduro Marsh. Percentage of potash too small to promise recovery costs competitive with other sources.

Cement. From annual normal output of 90,000,000 barrels of cement, some 90,000 tons K_2O might be recovered and this could be increased by half if higher potash-bearing materials were deliberately used; 14 plants equipped to recover potash could reclaim 15,000-16,000 tons, but are actually producing only 5,000 tons due to uncertain future; assured price and market would probably induce an output of 40,000 tons.

Blast furnaces. Another potentially great (100,000 tons K_2O annually) but practically small source; current recovery largely from wash-waters of gas-scrubbing towers; output would be increased by adapting Cottrell system to fumes; potash waste recovery not apt to continue unless price stays near $2.

Silicates. If and when techniques are perfected, might become the most important source: (1) Feldspar, no economic process yet for separation of potash; (2) leucite, the Boyer-Sterling interests, controlling largest available deposits, have million-dollar plant and able to produce 50 tons daily of 60% chloride at cost of $1.10 to $1.25; (3) Georgia shale (8% K_2O) worked at experimental plants at Portland, Georgia, and two near Louisville, all at loss, but eventual cost likely to be below $1.50 and proximity to fertilizer market an encouraging factor; (4) greensands (5 to 7% K_2O) called forth many efforts, but the one serious project to date could probably produce at $1 to 1.50; (5) alunite, Marysvale deposit runs 9% K_2O and worked by one large and two smaller companies; advantage of producing higher-priced sulfate and by-product alumina against disadvantage of distant location, cost delivered not less now than $2.

Molasses and Steffens waste. Best prospects among waste-recovery sources, may produce 30,000 tons K_2O and though present cost is close to $2, might still compete with German material.

Kelp. Weed contains 16% K_2O and ash 30%, but not a reasonable expectation unless chemical by-products—char, iodine, acetone, etc.—could be exploited profitably and potash become by-product.

Having faithfully set up these facts, Wells concluded that we might count on at least 75,000 tons of K_2O—roughly half our fertilizer requirements—at a cost of $1.25 to $1.50 per unit.

Seldom has Congress had a more understandable statement of tariff

---

* Sufficient to supply U. S. needs for 100 years. [See *Chem. Age* (*N. Y.*) *30,* 135 (1922).]

facts; never, a more sharply outlined tariff problem. Our dependence upon the foreign monopoly was as obvious as a blizzard. The danger of this dependence was not a nebulous, foreboding anxiety, but a grim reality. The chances of potash independence had been estimated and the costs calculated.

The proposed license-tariff bill was naturally advocated by the potash producers. They had invested some $35,000,000 during the war crisis, and a third of this had already been written off.[18] Though additional expenditures for research and plant revision would be needed, these would be forthcoming, if the industry had a chance of survival. The chemical importance of potash was pointed out to the Ways and Means Committee by Herbert H. Dow of the Dow Chemical Company and Lewis Emery, Jr., of the American Alkali & Chemical Company. The broader aspects of national self-interest were emphasized by Dr. Van H. Manning and Dr. George Otis Smith, heads, respectively, of the Bureau of Mines and the Geological Survey.

The farmers' organizations opposed this measure with great vigor. They protested an unwarranted increase in their mounting costs. That the measure was contrary to the traditional tariff policy of admitting basic raw materials duty-free and would create a bureaucratic control over prices, was the core of their argument. The fertilizer manufacturers, with one eye on their own costs and the other on their customers' interests, added their weight to the opposition.[19]

Congress was divided sharply and the pro and con positions stoutly maintained. To avoid facing a real issue squarely, the bill was again permitted to die. This cowardly evasion was made easier because of the impending presidential election. Congressmen rationalized their lack of courage by saying that regardless which party won, a new general tariff was sure to be on the legislative docket.

During the disturbing year of 1920, when German imports first seriously threatened, most of the 66 American potash plants operated hopefully more or less continuously. Their combined output was 166,834 short tons of crude salts (K_2O, 48,077).[20] Over 75 per cent of this came from brine and 88 per cent from members of the Potash Producers' Association.[21] Due to exceptionally favorable weather conditions, a record output was made by the solar-evaporation works of the Utah-Salduro Company which, though granted a land patent to 30,607 acres in the Great Salt Lake Desert, closed early in 1921, never to reopen.[22] Also during the year, three companies not destined to survive showed signs of activity: The Bonneville Company was planning to operate at the Salduro Marsh; the Eastern Potash Corporation went ahead equipping its greensands plant at New Brunswick, New Jersey, at a total cost of about $2,500,000;[23] the United States Potash Company, bravely started with a capital of \$5,000,000 by Howard S. Jefferson, Francis T. Whitney, and A. T. Wolfenden, planned to extract potash from Utah feldspar.[24]

Imports during 1920 totaled 225,000 tons of K_2O. During the earlier months, prices for imported material were little below domestic quotations, but as supplies became abundant and the depressing effect of the general deflation more evident, prices were cut and cut again. The spring season of 1921 found the market overloaded, prices sagging, and the American producers again closing down. Yet from the very depths of these doldrums there arose the one company that was to establish permanent production.

At Searles Lake, where the total potash investment was now nearly \$15,000,000, the Borosolvay plant was tapering off, preparatory to a final shutdown the end of the year.[25] A newcomer, the West End Chemical Company, was struggling with the G. P. Burnham solar-evaporation process. But the Trona plant was installing a new, double set of evaporators and a refrigerating unit, and planning again to expand. This company had already junked over \$1,500,000 experimental plants,[26] but in the words of Dr. John E. Teeple, the man who solved its difficulties, it faced the issue squarely, "either to succumb or to make a scientific and technical study of their problems such as they should have made in the first place. Most of them [the potash operators] elected the former procedure; it was easier and less expensive to die. The one at Trona chose the latter, and is selling its potash today [1928] at about 70¢ a unit without any particular difficulty, in competition with the German and French." [27]

When Teeple * was called in, he first undertook an exhaustive examination of the equilibrium data of five, 4-component systems leading up to the 5-component system of water and the chlorides, sulfates, and carbonates of potassium and sodium in the Searles Lake brine. These studies were made by William E. Burke, Harald de Ropp, and W. A. Gale.[28] Upon this factual foundation, a triple-effect evaporation process was eventually worked out for the continuous production of borax and potash. Removal of the sulfate and prevention of the formation of glaserite ($Na_2SO_4 \cdot 3K_2SO_4$) were helped by the discovery of the

---

* One of the outstanding, consulting chem. engs. of his day, Teeple not only played a big part in the development of the borax and potash from Searles Lake brine, but also of activated carbon, tartaric and citric acids, cream of tartar, and synthetic and C.P. chemicals. Educated at Cornell (Ph.D., 1903) he was a member of the Nat. Res. Council (1917-24) and for 12 years, treas. of the Am. Chem. Soc. His work was conspicuous for its searching thoroughness, backed by a rare and acute sense of business realities. His influence upon his profession was enhanced by the clear, pungent style of many articles and speeches in which he set forth his stimulating, common-sense ideas. Teeple died in N. Y. C., Mar. 23, 1931.

double salt, burkeite ($Na_2CO_3 \cdot 2Na_2SO_4$).[29] This and the complete separation of potash and borax, made possible by rapid cooling of the concentrated liquor to about 30° C., were vital steps in the operation. The process was not fully perfected in all details until a third new plant was built in 1924.[30]

In the early Trona development, complete separation of borax from the potash presented not only a tough technical problem, but also a definite commercial handicap in the fertilizer field. Complaints of crop injury by the Trona product, especially to tobacco and cotton in the eastern Carolinas and to potatoes in Maine,[31] were numerous and the Hubbard Fertilizer Company carried the issue to court in a test case by suing the American Trona Company for alleged damages of $275,000. Hubbard claimed breach of contract on the grounds that the potash delivered during 1918 contained borax in excess of the agreed specifications. The case came to trial in Baltimore, May 1922, and Judge Stanton of the Maryland Supreme Court rendered a decision holding Trona blameless. The fertilizer manufacturers had fixed their own specifications as to borax content and the potash delivered to them had met these specifications. Furthermore, at the first complaints, Trona had ceased shipping, closed down operations, and at great expense changed its process so as to produce a virtually borax-free material.[32] A few days after this decision was handed down, the Chief of the Bureau of Soils, Dr. Milton Whitney, gave Trona potash a clean bill of health, saying "salts produced in 1920-22 have a borax content of 0.27-0.5%, which compares favorably with the borax content of natural sodium nitrate." [33]

Over such a rocky road was the sole surviving potash producer of the war years forced to struggle. In 1921, most of its contemporaries, discouraged by the uncertainty of tariff protection in the face of real foreign competition, had already dropped by the wayside. Only 20 plants were working that year. They produced a total of 25,485 tons of crude salts, or 10,171 tons of K_2O against imports of 78,698 tons of K_2O.[34]

Efforts to get specific duties on potash in the Emergency Tariff (H.R. 2435), which passed the Senate, May 20, 1921, failed signally. The antidumping and American valuation clauses, providing special duties on goods sold here at lower prices than in the country of origin, were no protection whatever to American potash producers. The nationalistic policy of the old Potash Cartel had always made foreign buyers pay more than German consumers. Furthermore, at this time the mark's normal exchange value of 23.8¢ had shrunk to 1.5¢.

Accordingly, for the third time an attempt was made to get direct tariff protection. Discreetly the licensing scheme, very unpopular among farmers and quite vulnerable to attack, was dropped, and the general tariff bill (H.R. 7456), which passed the House that fall, carried duties of 2.5¢ per pound of K_2O on all potash salts for the next two years; 2¢ for the third year; 1.5¢ for the following years; 1¢ for the fifth year, after which potash would return to the free list.

A great fight was staged during December 1921, at the hearings on this bill before the Senate Finance Committee. The same alliance of farmer-fertilizer interests presented the now-familiar arguments. Among their more impressive witnesses were J. D. Cameron Bradley of the American Agricultural Chemical Company; S. D. Crenshaw of Virginia-Carolina, who spoke officially for the National Fertilizer Association; Dr. Frank App of two big farmers' organizations in New Jersey; T. C. Atkeson of the National Grange; and H. A. Huston, representative of the Kali Syndikat.[35] The argument at times became nasty. Admittedly the whole potash effort had not been generally profitable, yet the high prices of the war years called forth cutting sarcasm about profiteering at the expense of the farmer. On the other side, evidence of a working agreement to control prices and allocate markets between the French and German producers was presented, and the substantial financial interest of American fertilizer firms in German mines was laid before the Committee.[36] American fertilizer companies were also accused by the *Manufacturers' Record*[37] of paying the costs of anonymous propaganda against American potash, issued through N. W. Ayer & Son, a Philadelphia advertising agency. This was denied by C. H. MacDowell, president of the National Fertilizer Association.[38] Notwithstanding this official denial, the selfishness of the fertilizer makers in blindly opposing any tariff on any fertilizer raw material was sharply criticized throughout chemical circles.

The tenor of the hearings revealed the influence of the farm vote. Political friends of the potash industry, therefore, attempted to replace the proposed duties by an equivalent five-year bonus to be paid by the Federal Government on all domestic production.[39] This was rejected, August 9, 1922, by the Senate Finance Committee by a close vote. Thus the last lingering hope of protection for this truly infant industry, producing an essential chemical raw material, was buried deep.

In the meantime the Kali Syndikat had been reorganizing its war-torn ranks at home. By a smart deal with American potash buyers, in which the French mines shared, it undermined the position of its hard-pressed American competitors. The war had heaped troubles upon the German industry. The famous Law of 1910 had given a very low price to domestic consumers, and when the embargo of 1915 shut off all foreign sales, the German producers were caught in a trap. Their costs, especially fuel and labor costs, rose rapidly. They begged the Imperial Government for permission to raise their prices for domestic delivery. Grudgingly and piecemeal they were granted increased prices; concessions as to the exemption of miners from military service; allotments of fuel and shipping space on the railways.* Throughout hostilities, however, the Syndikat members complained bitterly that their essential industry was being starved to death. The closing of most of the mines corroborates that, quite aside from any profits or depletion reserves, they could hardly maintain their properties in decent working condition.

Premonition of Germany's defeat must also have disturbed them. As early as 1917 they were accusing the United States of seeking the return of Alsace-Lorraine to France in order that American fertilizer companies might control the rich potash deposits in that region.[40] At the end of the war, when the Alsatian mines were so restored, the Germans were positively panicky at the prospect of competition they knew could be damaging and which they suspected would be unequivocally hostile.

In a dither of nervous excitement, the Potash Law of 1910 was superseded by the Potash Law of 1919. This replaced the old Syndikat by the Reichskalirat (Federal Potash Council), with broader, more centralized powers. The "Kalirat," as the governing body was nicknamed, could, for example, fix prices, shut mines, prohibit sinking new shafts, and regulate hours and working conditions. It became obligatory for all active producers to join a compulsory cartel, and the new Kali Syndikat was organized October 16, 1919, with a nominal capitalization of 1,684,000 marks. Two results flowed directly from these benign but despotic measures. One fourth of the shafts were arbitrarily closed for 30 years. Many of the surviving companies were merged. Thus, in the economic jargon of the day, the German industry was "rationalized."[41]

Stripped for action in this summary fashion, the Syndikat turned its attention to rewinning the American market. Leading companies began cabling special inducements to old customers. Stock was sold to two large American fertilizer corporations. Prices were secretly cut by rebates. Particular efforts were made to secure long-term contracts for all of a buyer's potash requirements. By these methods American potash producers, fertilizer materials dealers, fertilizer manufacturers, and even American farmers were thrown into a turmoil.

This fishing in muddied waters was disastrous to the American potash producers. But it was not landing the contracts of the big buyers who shrewdly began playing one eager seller against the other. Accord-

---

* Modifications of the German Potash Law in favor of the producers were adopted Sept. 7, 1915; June 8 and 21, 1916; June 16, 1917; July 23, 1918; Dec. 27, 1918. (See H. M. Hoar, Bur. For. Dom. Com., *Trade Prom. Ser. No. 33*, 24.)

Kelp Products Plant, Summerland, Calif., 1918.

J. W. Turrentine, director (*right*), and Paul S. Shoaff, superintendent, of Summerland Kelp Products Plant, with first batch of potash.

ingly, during the winter of 1920-21, several high officials of the Syndikat came to this country to negotiate one big contract to supply our entire fertilizer industry with all its potash. This was treading dangerously close to the jurisdiction of our anti-trust laws, and American companies were chary of the proposal. Herman Duchessen of the Syndikat, therefore, went straight to Washington to obtain from the State Department permission to close such a deal. He failed only because he would not give dependable assurances that the contract would be made only for short-term commitments. Later, the State Department withdrew its objections, and on September 28, 1921, just before the Senate Finance Committee opened its hearings on the tariff, a contract between the Kali Syndikat and 34 American fertilizer manufacturers was signed, which smartly evaded the Anti-Dumping Act and sealed the death warrant of the war-born American potash industry.[42]

At a base price of 64 cents per unit, with certain discounts for large quantities, the Germans had tied up more than half of the American consumption of potash.* This sell-out of national interests "for a mess of potash" was widely resented. The *Manufacturers' Record* declared editorially that "this terrifying and un-American contract could not have been made unless sanctioned by the Economic Council at Berlin. It is the first great foreign victory for the 'Dach' trust, the Trust of Trusts." [43]

Unabashed by this criticism, the same group of fertilizer makers bought 13,482 tons of potash from the Société Commerciale des Potasses d'Alsace on November 17, 1921, and 45,000 additional tons from the same source were contracted for, on December 21, by the Associated Fertilizer Manufacturers, a cooperative buying group of 12 firms. Price and terms of both these French contracts [44] were identical with the German, and all three were to run till April 1922. Collusion between the two foreign cartels was self-evident.

German anticipation of unrelenting French competition had not been fulfilled. Taking no chances, the Kalirat hardly waited for the peace treaty to be signed, before it began flooding France with potash priced

* For text of contracts, see Senate Finance Comm. Hearings on Tariff Act of 1921 (H.R. 7456), pp. 4731-37. The American firms signing the contract were: American Agricultural Chemical Co., Virginia-Carolina Chemical Co., International Agricultural Corp., Armour Fertilizer Works, Swift & Co., F. S. Royster Guano Co., Arkansas Fertilizer Co., Baugh & Sons Co., Berkshire Fertilizer Co., Caraleigh Phosphate & Fertilizer Works, Darling & Co., E. Rauh & Sons Fertilizer Co., Federal Chemical Co., F. W. Tunnell & Co., Georgia Fertilizer & Oil Co., G. Ober & Sons Co., Griffith & Boyd, Gulf Fertilizer Co., I. P. Thomas & Son Co., Miller Fertilizer Co., Mutual Fertilizer Co., Olds & Whipple, Piedmont-Mount Airy Guano Co., Read Phosphate Co., Reliance Fertilizer Co., Richmond Guano Co., Robertson Fertilizer Co., Rogers & Hubbard Co., Smith Agricultural Chemical Co., Southern Fertilizer & Chemical Co., W. B. Tilghman Co., Wuichet Fertilizer Co., Wilson & Toomer Fertilizer Co., York Chemical Works.

below the production costs of Alsatian mines. This did not last long. In its June 30, 1920 issue, the *Frankfurter Zeitung* said: "Neither in France nor in Germany has the State or the producing industry any interest in spoiling prices. . . . An agreement between France and Germany as to potash prices on the world market would therefore be to the advantage of both." This inspired hint, from a newspaper long the mouthpiece of German chemical interests, was taken, and the Alsatian industry being also under State control, a working agreement with the German cartel was consummated with official sanction.*

Imports of potash during 1922 jumped to 210,415 tons of K_2O, while American production dropped to 11,714 tons. An even dozen companies had reported production, but by the end of the year only three were operating: American Trona at Searles Lake, United States Industrial Chemical at Baltimore, and Santa Cruz Portland Cement at San Francisco.[45] The Government kelp plant, which had outlived the private kelp enterprises, was sold early that year for $25,000 to the United States Kelp Products Corporation, of which Rodney Benson of Santa Barbara was president. This company ambitiously enlarged the plant and started up bravely, but in October it closed down.[46] All the remaining 128 companies active at the end of the war were either dead or dormant. Nevertheless, at this dark moment new life was quickening. Not only had the Trona Company shipped 30,000 tons of crude potash, averaging 96.5% potassium chloride, in 1923, but also 14,000 tons of pure borax.[47] Two other companies, the Inyo Chemical Company and the Burnham Chemical Company, were working experimentally at Searles Lake. Eight producers, mostly of by-product potash from cement dust and distillery waste, raised the 1923 output to 39,029 short tons of crude salts, 20,215 tons of K_2O. This was almost double the output of the previous year.[48] At the same time the first borings into the Permian salt beds of West Texas and New Mexico showed signs of vast underground deposits similar to those worked by the German and French industries.[49] Here were the new foundations—Searles Lake brines, cement and molasses by-product, and the Southwestern salt beds—upon which, during the next decade, the United States was to build potash independence.

REFERENCES

1. *O.P.D. Reptr.* 29 (Nov. 18, 1918), 28 (Dec. 2, 1918).
2. *Drug Chem. Mkts.* 13 (Aug. 14, 1918).
3. War Ind. Bd., *Price Bull. No. 47,* 16.
4. *Min. Ind. 1919,* 568.
5. *Drug Chem. Mkts.* 30 (Jan. 22, 1919).
6. *O.P.D. Reptr.* 28 (Mar. 3, 1919).
7. *Min. Ind. 1919,* 574.

---

* In 1924 the two allocated their sales to the United States on the basis of Germany, 62½%; France, 37½%.

8. C. L. Modesitt, to author, Sept. 27, 1943.
9. *Drug Chem. Mkts.* 9 (Dec. 25, 1918).
10. *Min. Ind. 1919,* 575.
11. *Chem. Met. Eng. 23,* 578 (1920).
12. *O.P.D. Reptr.* 54H (Aug. 18, 1919).
13. *Drug. Chem. Mkts.* 19 (Sept. 10, 1919), 25 (Oct. 29, 1919).
14. *Min. Res. 1919,* II, 85.
15. *J. Ind. Eng. Chem. 10,* 245 (1918); *Min. Ind. 1919,* 582.
16. Hearings on H.R. 4870, June-July, 1919.
17. A. E. Wells, Bur. Mines, *War Min. Invest. 1919,* 30 p.; reprinted, *Chem. Engr.* 27, 259, 283 (1919), *Am. Fertil. 51,* 63-121 (1919).
18. Hearings Finance Comm. on Tariff Act of 1921 (H.R. 7456), Dec. 20, 1921, p. 4784.
19. Hearings on H.R. 4870, *op. cit.*
20. *Min. Res. 1920,* II, 99.
21. *Min. Ind. 1920,* 566.
22. G. R. Mansfield, *J. Chem. Educ.* 7, 757 (1930).
23. *Drug Chem. Mkts. 6,* 1049 (1920).
24. *O.P.D. Reptr.* 29 (Aug. 25, 1919); *Min. Res. 1920,* II, 98.
25. Teeple, *Industrial Development of Searles Lake Brines,* p. 24.
26. A. C. Harragin, Hearings on H.R. 4870, *op. cit.* p. 11.
27. Teeple, *op. cit.* p. 25.
28. *Ibid.* p. 65, *seq.*
29. *J. Ind. Eng. Chem. 13,* 249 (1921).
30. Details in Teeple, *op. cit.; Ind. Eng. Chem.* 19, 318 (1927); R. W. Mumford, *ibid. 30,* 872 (1938).
31. M. Whitney, *Potash* 1, (June 16, 1922).
32. *Potash* 3 (May 26, 1922); *Drug Chem. Mkts. 10,* 1239 (1922).
33. *Potash* 1 (June 16, 1922); see also W. H. Ross and W. Hazen, *Chem. Met. Eng.* 27, 167 (1922).
34. *Min. Res. 1921,* II, 52, 56.
35. Hearings, pp. 4716-57.
36. *Ibid.* pp. 4757-92.
37. Dec. 15, 1921, p. 62; Dec. 22, 1921, p. 61; Jan. 5, 1922, p. 75.
38. *Ibid.* Jan. 19, 1922, p. 52.
39. *O.P.D. Reptr.* 19 (June 19, 1922), 21 (Aug. 14, 1922).
40. *Ibid.* 20 (Nov. 19, 1917).
41. H. M. Hoar, Bur. For. Dom. Com., *Trade Prom. Ser. No. 33,* 23-30; Stocking, *Potash Industry,* pp. 149-94.
42. Fed. Trade Comm., *Report on Fertilizer Industry,* 1923, p. 30; Hoar, *op. cit.* p. 84; *Drug Chem. Mkts. 9,* 1187 (1921), *10,* 78 (1922).
43. Dec. 15, 1921, p. 62.
44. Hearings on Tariff Act of 1921, *op. cit.* pp. 4768-77.
45. *Min. Ind. 1922,* 581; Teeple, *J. Ind. Eng. Chem. 14,* 787 (1922).
46. *Chem. Met. Eng. 26,* 758 (1922); J. W. Turrentine, *Chem. Age* (*N. Y.*) 30, 224 (1922).
47. *Min. Res. 1923,* II, 175.
48. *Ibid.* 168.
49. *Ibid. 1921,* II, 54; *1922,* II, 95.

Chapter 16

PHOSPHATE ROCK AND ELEMENTAL PHOSPHORUS

WAR COST U. S. LEADING POSITION AS WORLD SUPPLIER OF PHOSPHATE ROCK—WESTERN DEPOSITS RISE AND FALL—WAR DEMANDS FOR ELEMENTAL PHOSPHORUS MET BY OLDBURY—SWANN DEVELOPS ELECTRIC-FURNACE PROCESS—TARIFF OF 1922 PROTECTS NEW PHOSPHORUS CHEMICAL MAKERS.

AT THE OUTBREAK of World War I, phosphate rock and naval stores, both from the South, were the only important, nonmetallic chemical raw materials in which the United States held a predominant position in international trade. The Union Sulphur Company, operating the Frasch hot-water process in Louisiana, had the whip hand over the old Sicilian sulfur monopoly and had compelled an advantageous trade truce. Nevertheless, its output had actually passed the Sicilians' only two years earlier, and its export tonnage was but a fractional share of the world total. Furthermore, pyrites was still the chief raw material of the American sulfuric acid manufacturers.

In borax we had just achieved independence, importing a mere 466 pounds in 1914.[1] F. M. (Borax) Smith, who had discovered the famous Death Valley deposit back in 1872, sold out his controlling interest in the Pacific Coast Borax Company in 1913, and the year the war broke out, the new management built a narrow gauge railroad connecting these mines with the Tonopah & Tidewater Railroad.[2] However, the extensive deposits in Asia Minor and South America occupied an authoritative place in the London market where world borax activities centered. Wartime expansions put American sulfur and borax in first place, but these commercial conquests were still to be made in 1914.

At that time, however, American phosphate rock was strongly entrenched, commanding the world markets. In fact, the United States had been the largest producer since 1867, when the deposits in South Carolina were first mined. In 1913 we supplied 76 per cent of 7,000,000 tons, then the world total. Quite the contrary to the war's effects upon sulfur and borax, the interruption of ocean shipping presented competitors of the American phosphate rock industry with an opportunity which they grasped so successfully, that during the 1920's control of the European market actually passed to the North African suppliers. Moreover, rock from various South Sea islands became a factor with which domestic producers were forced to reckon in Japanese and Australian markets. Having lost their facile command of foreign markets, American rock producers perforce cultivated intensively the domestic field.* Phosphate was notably emphasized as a plant-food element. This policy was fostered by several large fertilizer manufacturers who were also owners of extensive phosphate lands in Florida and Tennessee.

The influences of the war were felt in other directions in the phosphate industry. They encouraged more efficient mining methods and more thoroughgoing recovery processes. Finally, and from the chemical point of view exceedingly important, the war demand for phosphorus steel and for phosphorus compounds in tracer bullets, incendiary and smoke bombs, together with the manufacture here for the first time, of "safety matches," promoted production of phosphorus. This culminated in the blast and electric-furnace methods for producing both acid and element. These developments eventually brought two large chemical companies, Victor and Monsanto, and one rock producer, the Phosphate Mining Company, into the production of elemental phosphorus. They also helped to diversify the products of two large fertilizer manufacturers, the American and International Agricultural Companies. Both the inorganic and organic horizons of the phosphate family were widened by a commercial supply of phosphorus and pure phosphoric acid at reasonable prices. New chemicals important to the textile, lacquer, plastics, insecticide, petroleum, soap, and other industries resulted.

While the big tonnage of phosphate rock used in fertilizers always eclipses its employment as a chemical raw material,† the manufacture of phosphoric acid and of phosphates, at that time mainly for baking powder,‡ was already a growing branch of the chemical business. During the war, phosphates began to be used for detergents in a really big way and became the outstanding chemical product, from a tonnage point of view, of all the phosphorus group. Technical refinements in the chemical process for making phosphoric acid were achieved in response to greater demands for phosphates, and it continued, even after the practical application of the thermal process in the late 1920's, to be the base for a large portion of our phosphates.

In 1914, however, the chemical demand for phosphate rock was so insignificant—but 90,000 tons out of a total of nearly 3,000,000—that the miners ignored it. This simplified their selling problem, but it made

---

* For U. S. export figures, see Appendix XXIX. For a capital general discussion of the phosphate rock industry, with full official statistics and good early bibliography, see B. L. Johnson, Bur. Mines, *Inform. Circ. No. 6256* (1930).

† Phosphate rock consumption data are in Appendix XXIX.

‡ For export figures, see Appendix XXXI.

them utterly dependent upon the fertilizer industry. At the outbreak of the war, their fertilizer market was in bad shape and there was little they could do about it.

For many years there had been a fairly steady increase in both foreign and domestic consumption of rock. After the boom days, when there was a rush to exploit the new-found Florida deposits,* competition had struck a trade equilibrium which even the discovery of the Tennessee fields did not disastrously disturb. Florida hard rock was exported. Florida land-pebble phosphate went by boat to the fertilizer makers along the Atlantic seaboard. Tennessee rock was consumed in the Middle West. The markets were sharply bounded by freight rates and there was little poaching on the other fellow's preserve.

Prices were based upon quality with openly determined differentials equitable to both buyer and seller. Values were calculated upon the content of tricalcium phosphate, $Ca_3(PO_4)_2$, commercially known as bone phosphate of lime (B.P.L.). Florida hard rock had long been sold abroad on the basis of 77% B.P.L., with a 25 cents pro rata unit rise for material analyzing above this agreed percentage and a 50 cent per unit penalty for lower-grade rock. Even before the war the combined content of iron and aluminum impurities (I. & A.) were commonly guaranteed in export contracts. Buyers received a bonus of two units of B.P.L. subtracted from the analysis if the I. & A. exceeded the agreed maximum. Contrariwise, sellers were beginning to ask, and buyers were more and more willing to concede, that if the analysis showed less I. & A. than guaranteed, they should have a unit of B.P.L. added to their credit.

In the domestic market the scale of differentials had not been so well worked out. But the principle of a price based on B.P.L. content was thoroughly established.[3] These practices gave a certain stability to the price structure and for years quotations had been reasonably steady. Sales in tonnage, by ship or carload, to the larger fertilizer manufacturers were handled by the mining companies direct. Smaller customers were served through well-established, reputable brokers in New York, Baltimore, and Charleston. These dealers assumed the credit risks and arranged the details of delivery. Phosphate mining was a pleasant and generally profitable business.

It also appeared to be a remarkably substantial enterprise. Phosphate was an essential ingredient in a necessary commodity. Its consumption ran into millions of tons. The technique of its employment in fertilizer manufacture was so simple and cheap that the process seemed invulner-

---

* More than 100 companies were organized to work the Florida lands; in 1914 only 36 had survived. [See *Chem. Ind. 36,* 531 (1935); *Am. Fertil. Hand Book, 1913,* 113; *1914,* C-10; *1915,* C-11.]

able.* American farmers were using more and more fertilizer and their need to do so was bound to become increasingly indispensable as they harvested crop after crop. Reserves of both the Florida and Tennessee deposits were measured in hundreds of years. Only a soothsayer could have foreseen in 1914 the changes and the difficulties that lay ahead of the phosphate rock miners.

True, the 1913 market had been off and the 1914 demand was discouraging. The years 1911-12 had been banner fertilizer seasons, but the decline in all commodity prices following Wilson's election, accelerated after the passage of the "revenue-only" Underwood Tariff, had cut the farmer's income. As usual he had economized on fertilizers. Accordingly, both the output and price of phosphate began to decline in 1913. In the opposite direction to the strong war-borne currents, both continued downward for the next four years. During this period the gross annual income of the industry was cut from $11,796,231 to $5,896,993.[4] At the same time costs were mounting fast.

After our entry into the war in 1917, both production and prices of phosphate rock rose. During that and the two following years, output hovered around the two-and-a-half million-ton mark. For the first time on record domestic consumption passed 2,000,000 long tons. In July 1917, the price had returned to the prewar level—Florida land pebble, $3 a ton [5]—and it rose to $5 a ton at the Armistice, after which it tapered off, only to shoot up again in the 1919-20 boom.[6] Throughout the war period, there was a chronic surplus of phosphate rock, which in times of shipping stringencies piled up embarrassingly.

In 1913, in the Florida field, 16 companies were mining land-pebble phosphate and 14 hard-rock phosphate. About 46 per cent of the output, or 1,161,117 long tons, was produced by the three largest fertilizer manufacturers, American Agricultural Chemical, Virginia-Carolina, and International, and for several years the interest of fertilizer makers in phosphate operations had been growing.

The American Agricultural Chemical Company had acquired phosphate lands estimated to have reserves of over 75,000,000 gross tons and, through subsidiaries, controlled 55,000 acres of likely Florida land which had not been thoroughly prospected. In the land-pebble field, it operated through two subsidiaries, the Pierce Phosphate Company at

---

* Production of fertilizer superphosphate depends on the reactions: $Ca_3(PO_4)_2 + 2H_2SO_4 + 4H_2O = 2(CaSO_4 \cdot 2H_2O) + CaH_4(PO_4)_2$. Theoretically, to change completely 310 parts by weight of insoluble tricalcium phosphate (pure phosphate rock) into soluble monocalcium phosphate and gypsum requires 196 parts of pure sulfuric acid and 72 parts of water; or for 1 ton of rock, 0.63 ton of acid and 0.23 ton of water. Commercially equal quantities of pulverized rock and 50-55° Bé. acid (chamber acid, containing 30-38% water) are used. (See Waggaman and Easterwood, *Phosphoric Acid, Phosphates, and Phosphatic Fertilizers,* p. 164.)

Pierce and the Palmetto Phosphate Company at Tiger Bay. It owned 2,000 acres of unprospected phosphate land in Tennessee. In the export field it was represented by the hard-rock Florida operations of the Boston firm of Peter B. & Robert S. Bradley, owned by the moving spirits in the original merger of the parent company. The company had also built the Charlotte Harbor & Northern Railway, tapping its pebble phosphate fields with 120 miles of track terminating at the deep-water shipping point of Charlotte Harbor, Florida.[7]

The Virginia-Carolina Chemical Company mined phosphate rock through three subsidiaries: Charleston (S. C.) Mining & Manufacturing Company, United Phosphate & Chemical Company, and Amalgamated Phosphate Company. In the last company, which operated at Chicara, Florida, a half interest was held jointly by Baugh & Sons Company, fertilizer makers of Philadelphia; H. J. Baker & Bro., fertilizer materials brokers of New York; and Wilson & Toomer Fertilizer Company of Jacksonville. This was the phosphate property which in 1915 was acquired by the Ammo-Phos Corporation, in which James B. Duke, Virginia-Carolina, and the American Cyanamid Company were all interested. Virginia-Carolina and its subsidiaries owned 9,620 acres of Florida land-pebble land, 12,811 acres of Tennessee brown and blue rock, and 53,370 acres of South Carolina rock, a total estimated reserve of 47,000,000 tons.[8]

Phosphate lands owned by the International Agricultural Corporation and its subsidiaries, the Florida Mining Company and the Peoria Pebble Phosphate Company, both of Mulberry, Florida, totaled in 1913 some 39,000 acres in Florida, with an estimated 37,712,895 gross tons of pebble rock. In the state they were operating eight mining stations and washing plants and two central drying plants, all served by 33 miles of company-owned railway. In the Tennessee field International's phosphate property consisted of 4,324 acres estimated to contain 6,500,000 tons of brown and 6,000,000 tons of blue rock. Through its subsidiary, the Independent Phosphate Company, it controlled 2,103 additional acres of land only partly appraised, but supposed to contain 105,000 tons of brown and 7,500,000 tons of blue rock. On these Tennessee properties it was operating eight mining stations.[9]

The F. S. Royster Guano Company owned beds of Florida pebble rock sufficient, it was claimed, to meet its raw material requirements for 40 years. At Bartow, in Polk County, it was operating a mine and washing plant through its subsidiary, the Florida Phosphate Mining Company. Both Armour and Swift were also producing their own phosphate. About one-third of Armour's annual requirements was supplied from one mining operation in Florida where the Company owned beds of 240 acres, while in Tennessee it had 85 acres of brown rock land and 215 acres of blue rock property.[10] Swift, on December 27, 1913, absorbed its subsidiary, the State Phosphate Company, which had been incorporated in West Virginia for $100,000 and owned Florida beds said to contain 1,645,000 tons of pebble rock.[11] Swift also owned 374 acres of phosphate lands in Tennessee and had mining rights to 362 additional acres.

An important factor in the Florida land-pebble fields was the Phosphate Mining Company of Nichols, a subsidiary of Peters, White & Company, New York fertilizer brokers. Two French companies also operated in this field. The Compagnie Générale des Phosphates de la Floride properties at Pembroke were taken over in 1913 for more than $1,000,000 by the Coronet Phosphate Company of New York.[12] The Société Franco-Américaine des Phosphates de Medulla was operating at Christiana, the mine and plant acquired from the Standard Phosphate Company. Other firms mining this field were the Dominion Phosphate Company at Bartow, the International Phosphate Company at Fort Meade, and the Interstate Chemical Company, fertilizer manufacturers of Charleston, South Carolina, with mines at Bowling Green.

In the hard-rock field, whence the phosphate was mostly shipped abroad, only one American fertilizer manufacturer was active, the Mutual Phosphate Company of Savannah, which operated at Newberry as the Mutual Mining Company. Two German firms, J. Buttgenbach & Company at Holder, and Schilman & Bene at Ocala, Florida, had been established here. Both were later taken over by the Alien Property Custodian. Among the great number of independent miners of hard rock were: P. Bassett, successor to the Central Phosphate Company at Newberry; Camp Phosphate Company owned by C. and J. Camp, Ocala and Dunnellon; Cummer Lumber Company at Newberry; Dunnellon Phosphate Company, Rockwell; Dutton Phosphate Company, Gainesville; Franklin Phosphate Company, Newberry; Holder Phosphate Company of Cincinnati and Inverness; Istachatta Phosphate Company at Istachatta; Southern Phosphate Development Company, Ocala and Inverness; T. A. Thompson, Neals. During 1914 two additional companies appeared in the field: the Acme Phosphate Company of Chicago operating at Morristown and Meredith-Noble Phosphate Company of Romeo, Florida.[13]

As in Florida, so in Tennessee, the greatest production came from large fertilizer companies and their subsidiaries. In this region, during 1913, American Agricultural Chemical, International Agricultural, and Virginia-Carolina together mined 247,000 long tons, or about 55 per cent of the Tennessee total. Besides this trio, Armour and Swift had unworked property in this section, while the Federal Chemical Company, fertilizer manufacturers of Louisville, Kentucky, was the fourth largest producer from its properties at Columbia, Tennessee. The next important tonnage was mined by the Standard Phosphate & Chemical Company. After these five, the balance of the total Tennessee production of 451,559 long tons[14] came from eight domestic producers: the Blue Grass Phosphate Company, Mount Pleasant; Corn Belt Phosphate Company, Centerville; Farmers' Ground Rock Phosphate Company, Mount Pleasant; Morgan Mining Company, Columbia; Natural Phosphate Company, Nashville; Petrified Bone Mining Company, Mount Pleasant; Preston Mining Company, Columbia; Ruhm Phosphate Mining Company, Mount Pleasant; and one foreign-owned company, Central Phosphate Company at Mount Pleasant.

The tough sledding of the war years hastened the final abandonment of the historically famous South Carolina phosphate properties. Ever since the discovery of the richer, more economically worked Florida fields, the output from South Carolina had been steadily dropping. During the decade previous to the outbreak of the war, production had fallen from 270,000 tons (1904) to but a little over 100,000 tons (1914). Before the end of hostilities, although insignificant quantities continued to be mined for local use, commercial production had dropped to nil.

On the other hand, conditions on the West Coast during the war stimulated production of phosphates in Utah, Idaho, Wyoming, and Montana.* Initial production in the Western fields had been reported in 1909. Production in 1910 had been 9,493 long tons, but by 1913 and 1914 it declined to 5,053 and 5,030, respectively. In 1917 there was the astonishing increase of 786 per cent, the output being 15,096 tons from four producers, the San Francisco Chemical Company, the Western Phosphate Mining & Manufacturing Company, Peter B. & Robert S. Bradley, and the Union Phosphate Company, compared with but 1,703 tons from two producers in 1916.[15] In 1918 shipments decreased 21 per cent in these states, but their value increased from an average of $2.77 per ton to $3.53. That year one producer, Union Phosphate, discontinued operations.[16] Abnormal conditions—war demands for phosphate chemicals and shipping difficulties from the Eastern fields—cleared up in 1919 and the unnatural demand for Western rock vanished. That year Western mines curtailed production and filled what orders they had from their stockpiles.[17]

Interest in these Western properties rallied unexpectedly in 1920. Having taken over the San Francisco Chemical mine at Montpelier, the newly organized American Phosphate Corporation resumed operations and began building a washing plant. This year, too, the Anaconda

---

* For bibliographies of Western deposits, see Waggaman and Easterwood, *op. cit.* p. 76; Johnson, *op. cit.* p. 9, which gives later titles.

Copper Mining Company, plagued by sulfur gases in its smelter fumes, began experimenting with their recovery as sulfuric acid. At two deposits owned near Montpelier, it began experimenting with the manufacture of triple superphosphate and planned to collect acid from several smelters at a new plant to be built near its phosphate rock deposits at Soda Springs, Idaho.[18] Again, progress by injunction scored, for this compulsory waste recovery resulted in what became the first permanent commercial employment of Western phosphates. It led, years later, to the important fertilizer developments at Trail, British Columbia, by the Consolidated Mining & Smelting Company.[19] During 1920 abortive development work was carried on by the Bear Lake Phosphate Company and the Montana Phosphate Company, but the following year, the Western Phosphate Company, which had been mining in Idaho since 1917, went into a receivership and the Merriman Potash Products Company also stopped mining.[20] The Bradleys, who of all the Eastern phosphate producers had alone entered the Western field, gave up this experiment in 1919.

These Western ventures were entirely aberrant. The war had temporarily wiped out the disadvantages of their inaccessible location. It had brought no such boom, however, to the established Eastern mines which conspicuously among all producers of chemical raw materials were hurt rather than helped by war conditions. The Tennessee fields were less affected than those in Florida and South Carolina, for they had no export business to lose and no cargo ships to be commandeered for military use. The Eastern miners found 1916 a bad year, if not so bad as 1915, but 1917, due to shipping strangulation, proved worse. Florida operators, handicapped by shortages of fuel oil and labor, lost most of their export business, and after the Government began taking over cargo ships, even domestic, coastwise deliveries became very difficult. A number of superphosphate plants north and east of Norfolk and Baltimore were forced to close down for lack of raw material, and at the mines, despite curtailed production, the stockpiles mounted.

Just when the uncomfortable dependence of the phosphate rock miners upon the fertilizer industry became painfully apparent, new uses began to develop which were to diversify their market. At that time, 95 per cent of the phosphate rock produced in the United States was consumed east of the Mississippi River[21] and 90 per cent went into superphosphate.* Of non-fertilizer uses, the productions of elementary phosphorus, phosphoric acid, and dicalcium and tricalcium phosphates were the most important. During the war, from the tonnage point of view, ferrophosphorus came first, its use in phosphorus-bearing steels

* See Appendix XXIX.

and alloys being greatly increased by munitions needs. Purchasers of rock to smelt with iron ore or scrap iron during this period included the Federal Phosphorus Company of Birmingham; Ohio Ferro-Alloys Corporation of Canton, Ohio; Tennessee Products Corporation and the Warner Iron Company both of Nashville.[22] Phosphate rock was also added to the blast-furnace charge either occasionally or as standard practice, by 28 iron and steel companies.[23]

Chemical utilization of phosphorus has been based either upon the element itself or on phosphoric acid, starting in either case with the preparation of the acid.* Originally bone ash, later phosphate rock, was leached with sulfuric acid in lead-lined tanks. The phosphoric acid thus produced was separated by filtration and concentrated by means of evaporation, and if the element was desired, the acid was mixed with carbon (charcoal or coke) and the mixture subjected to high temperature in clay retorts.[24] Clumsy and time-consuming, this so-called "wet process" was wasteful at every step, and the final concentration and purification were excessively costly. Its technical improvement during the First World War period was a major advance.

As early as 1867 Auberton and Boblique had secured a patent for volatilizing and collecting elementary phosphorus from pulverized mixtures of phosphate rock, sand, and coke, heated to a high temperature in closed containers. Giles and Shearer took out the first American patent [25] in this field and in 1889 Readman was the first to propose the use of the electric furnace.[26] From this time forward the volatilization idea was tried out in a number of forms and with various modifications.†

During 1915 and 1916, actuated by the scarcity and high price of sulfuric acid, as well as by new war demands for phosphorus compounds, Ross, Carothers, and Merz of the Bureau of Soils began extensive experimental work on the volatilization process in an electric furnace.[27] Eventually they solved the old problem of complete, economical recovery of the P_2O_5 fumes by an adaptation of the Cottrell electrical precipitator.[28]

Shortly after the outbreak of the war, Theodore Swann,‡ super-

---

* See Appendix XXX for production and imports.

† For a review of these experiments and the patent literature, see Waggaman and Easterwood, *op. cit.* pp. 210-16.

‡ Swann at twenty entered the electrical business as a local contractor in Bristol, Va., later joining Westinghouse as an industrial salesman and in 1912 entering the utilities field as commercial mgr. of the Virginia Power Co. During the war he was sales mgr. of the Alabama Power Co. He organized the Southern Manganese Corp. and the Swann Corp. in 1917, and in 1936 sold out to Monsanto, whereupon he formed Swann & Co., makers of fine synthetic chemicals. During the war he served on the Naval Consulting Bd. and was in charge of the important Birmingham Ordnance District for the Army. He has been a vigorous protagonist of higher education and the development of natural resources in the South for which public services he received hon. degrees from Oglethorpe and Alabama Polytechnic.

salesman of the Alabama Power Company, who disposed of electrical energy by bringing new companies into the utility's territory, grasped the opportunity created by the enormous war demand for ferromanganese and ferrochrome alloys, to organize the Southern Manganese Corporation. He built an electric furnace of eight large units at Anniston, Alabama, and in 1918 the War Department approached him to produce elemental phosphorus for smoke-screen work. Swann agreed to do this and on July 21, 1918, incorporated the Federal Phosphorus Company. Before the new plant could get into operation, however, the close of hostilities ended the War Department's immediate interest in additional phosphorus supplies.[29] Demand for his manganese and chrome-alloy ingredients had also dried up. Swann resourcefully turned his attention to ferrophosphorus, which promised to be more profitable, and to the pyrolytic production of phosphoric acid, whose recovery from the fumes was a perfectly natural development. He took over where the Arlington experiments of Ross and coworkers had left off and by 1921 had worked out a commercial process. At first a low-grade acid was produced, but by 1922, production centered on a 75° acid of high purity, particularly adaptable for the baking powder and chemical industries. Federal Phosphorus put into operation three electric furnaces, totaling 10,000 horsepower,[30] and during the later twenties this output became an effective part of the phosphate market.*

Before the World War, elemental phosphorus and phosphoric acid had limited uses and their production in this country had been periodically harassed by cutthroat foreign competition. During the war, military uses increased the demand for these products greatly, and the output of elementary phosphorus, which in 1914 was 1,315,000 pounds, multiplied by five.[31] Phosphorus was used in small-arms tracer bullets and in hand and rifle grenades by all belligerents, in artillery incendiary shells by the Germans and French, in trench mortar bombs by the British and Americans. In all these munitions, except the small-arms bullets, phosphorus produced both smoke and incendiary effects, and while both the red and white forms were used, the white was by far the most effective and widely employed.[32] General Amos Fries, Chief of the Chemical Warfare Service, later reported that the requirements for the Army had been 560 tons per month. Peacetime consumption was estimated to have been about 1,000 tons per year, nearly half of which went to the match industry.[33]

Prior to the war, most of the safety "strike-on-the-box" matches had been imported. Shipping difficulties made manufacture here imperative and created a demand for red phosphorus and phosphorus sesquisulfide.

---

* See also Vol. III, Chap. 4.

Other phosphorus compounds whose use was accelerated by the war were calcium phosphide for distress signals at sea, copper and tin phosphides for the production of phosphor bronzes, zinc phosphide for medicinal uses, and phosphorus chlorides for the manufacture of acetic anhydride and of chlorine derivatives in organic syntheses.[34]

During the war there were only two important American producers of phosphorus. The Oldbury Electro-Chemical Company at Niagara Falls, managed by F. Austin Lidbury, was jointly owned by the United Alkali Company of England and J. L. & D. S. Riker, New York chemical merchants. The latter handled the sales both of phosphorus and potassium chlorate for Oldbury in the United States. The American Phosphorus Company of which Charles W. Ashbury was president, had general offices in Philadelphia and a plant near Harrisburg. The mainstay of supply was Oldbury which stepped up its phosphorus production to a rate of some 5,000,000 pounds a year. The American Phosphorus annual output was in the neighborhood of 300,000 pounds. In 1918 the War Department contracted with American Phosphorus for construction of a new plant near Fairmont, West Virginia, to cost about $500,000,[35] but at the stage of blueprints and plantsite clearing this contract was canceled and awarded to Oldbury. This was done at the same time the War Department interested Swann in the production of phosphorus by electric-furnace methods. During the war the Diamond Match Company made some phosphorus in an experimental way in a small plant.[36]

By 1922, therefore, the phosphorus chemical industry was set for further development. The wet process had been simplified, its yields increased, and the purity of the products raised by means of the continuous, countercurrent decantation system instead of the old filtration methods.[37] The electric-furnace process had been perfected to the point of economical commercial yields. Elemental phosphorus and phosphoric acid—both of high purity, in large quantities, at reasonable prices—were available for the first time. One big question, however, continued to loom in the path of this new development: Would this branch of the chemical industry be able to establish itself in the face of foreign competition? The record of the past was disheartening. The lower rates of the Underwood Tariff had brought in strong foreign competition, and though this stopped during the war, present prospects were not bright. Already one of the two established producers, the American Phosphorus Company, closed its plant November 1921, because it did not have the diversity of products made by Oldbury.[38]

Under the Underwood Tariff phosphorus had come in free. Accordingly, when the Senate Finance Committee held hearings on the Tariff Act of 1921, efforts were made to secure protective duties for both phosphorus and phosphoric acid. The case for phosphorus was argued by W. A. Becker of the Diamond Match Company and Charles W. Ashbury of the American Phosphorus Company.[39] They were successful, and phosphorus imports were made dutiable at 8¢ a pound in the Tariff of 1922, which also continued the 2¢ a pound tariff on phosphoric acid.

Meanwhile, the miners of phosphate rock were readjusting themselves to the new postwar conditions. Their chief foreign competitors, the mines in North Africa, had immeasurably strengthened their position, quadrupling their output from 1,607,000 metric tons in 1910, to 4,232,000 in 1920.[40] While our 1920 phosphate rock exports jumped up to over 1,000,000 long tons, filling the accumulated European shortages of the war, they dropped back in 1922 to 733,312 tons and remained close to this figure for the next seven years.[41] In an effort to retain a place in the world markets, the following companies organized themselves as the Phosphate Export Association, in May 1921, under the provisions of the Webb-Pomerene Law: International Agricultural Corporation, Coronet Phosphate Comany, Phosphate Mining Company, Southern Phosphate Corporation, Florida Hard Rock Phosphate Export Association, Cummer Lumber Company, Dunnellon Phosphate Company, and Mutual Mining Company.[42]

In the domestic markets, however, consumption moved up from 1,250,000 in the 1906-9 period, to over 3,000,000 tons in the boom year of 1920. Once the price adjustment of 1921-22 was settled, consumption of phosphate rock in the United States consistently exceeded 2,000,000 tons for the following decade.

REFERENCES

1. *Min. Ind. 1915*, 64.
2. *Ibid.* p. 63; *O.P.D. Reptr.* 48 (Oct. 27, 1913); *Fortune* 40 (Nov. 1932).
3. R. W. Stone, "Phosphate Rock," in Spurr and Wormser, *Marketing Metals and Minerals*, pp. 471-77.
4. War Ind. Bd., *Price Bull. No. 48*, 8.
5. *O.P.D. Reptr. Yearbook, 1918*, 37.
6. Johnson, Bur. Mines, *Inform. Circ. No. 6256*, 54, 57.
7. Fed. Trade Comm., *Report on Fertilizer Industry*, 1916, p. 202.
8. *Ibid.* p. 193.
9. *Ibid.* p. 210.
10. *Ibid.* p. 206.
11. *Ibid.* p. 213.
12. *Ibid.* p. 100; *O.P.D. Reptr.* 10 (July 28, 1913).
13. Fed. Trade Comm., *op. cit.* p. 100.
14. *Ibid.* p. 102; *Am. Fertil. Hand Book 1914*, C6.
15. *Min. Res. 1917*, II, 110.
16. *Ibid. 1918*, II, 202.
17. *Min. Ind. 1919*, 535.
18. *Min. Res. 1922*, II, 118; *1923*, II, 254.
19. Haynes, *Stone That Burns*, p. 272.
20. *Min. Res. 1920*, II, 33.
21. Johnson, *op. cit.* pp. 21, 64.
22. *Ibid.* p. 61.
23. *Ibid.* p. 63.
24. J. B. Readman, *J. Soc. Chem. Ind. 9*, 163 (1890).
25. U. S. Pat. 393,428 (Nov. 27, 1888).
26. U. S. Pat. 417,943 (Dec. 24, 1889).
27. *J. Ind. Eng. Chem. 9*, 26 (1917).
28. *Ibid.;* W. W. Strong, *Trans. Am. Electrochem. Soc. 31*, 415 (1917); A. A. Heimrod and H. D. Egbert, *Chem.*

Met. Eng. 19, 309 (1918); N. H. Gellert, *Blast Furnace Steel Plant* 7, 334 (1919).

29. C. H. Penning, *J. Chem. Educ.* 7, 2370 (1930).
30. *J. Ind. Eng. Chem. 14,* 630 (1922); *Mfrs. Rec.* 51 (Apr. 13, 1922).
31. Tariff Comm., *Dictionary of Tariff Information,* 1924, p. 564.
32. Prentiss, *Chemicals at War,* p. 252.
33. Hearings Finance Comm. on Tariff Act of 1921 (H.R. 7456), p. 1286.
34. Johnson, *op. cit.* p. 21, Tariff Comm., *Tariff Inform. Surv. No. FL-1,* 22 (1921).
35. *Drug Chem. Mkts.* 13 (Oct. 9, 1918); *O.P.D. Reptr.* 46 (Oct. 14, 1918); *J. Ind. Eng. Chem. 10,* 951 (1918).
36. W. A. Becker, Hearings on Tariff Act of 1921, *op. cit.* p. 1280.
37. Waggaman and Easterwood, *Phosphoric Acid, Phosphates, and Phosphatic Fertilizers,* pp. 195-98.
38. Hearings on Tariff Act of 1921, *op. cit.* p. 1284.
39. *Ibid.* p. 1280.
40. *Fertil. Rev. 13,* 23 (July-Aug. 1938).
41. *Ibid.* p. 19.
42. *Drug Chem. Mkts. 8,* 1213 (1921).

Chapter 17

PYRITES TO BRIMSTONE

UNION SULPHUR COMPANY POISED TO CAPTURE WORLD MARKET—CURTAILED PYRITES SHIPMENTS FROM SPAIN AND DISAPPOINTING OUTPUT FROM U. S. MINES FORCE ACID MAKERS TO ADOPT SULFUR—CRITICAL SHORTAGES NECESSITATE RIGID CONTROL OF ALL SULFUR MATERIALS.

LESS SENSATIONAL than the rough-and-tumble rush to provide our potash needs, not so well known as the desperate fight to build a domestic coal-tar chemical industry, the revolution in sulfur was nonetheless one of the most fundamental changes wrought by the First World War in our chemical activities. American sulfur emerged from the struggle dominant in world markets. Once the enormous deposits of the Gulf Coast region had been successfully tapped by the Frasch hot-water process, it was obvious that the ancient Sicilian monopoly was sooner or later to be broken. The events of 1914-18, here and in Europe, hastened that day of doom. If viewed closely by American eyes, the replacement of foreign pyrites as the principal source of our sulfuric acid by brimstone from Louisiana and Texas was an even more significant change. Both developments sprang from the war.

The stage was set for the shift of international headquarters of sulfur from Sicily to the United States. After years of heart-breaking, cut-and-try experimenting, Herman Frasch [1] had whipped the technical difficulties of his hot-water process. In 1901, the fabulous gush of oil at Spindletop only sixty miles away had solved the economic problem of cheap fuel for the boilers of his sulfur-mining operation.[2] The Union Sulphur Company's production figures leaped forward from less than 5,000 long tons in 1902 to over 200,000 in 1905.[3] This tonnage just about balanced current American consumption of brimstone, but little of it went to acid makers. The Kalbfleisch and Grasselli companies consumed some, for they made a specialty of extra strong, notably pure sulfuric acid. But the rest of the chemical industry and the whole of the fertilizer industry, with the exception of the Chrome, New Jersey, plant of the Armour Fertilizer Works (designed by Kalbfleisch),[4] were operating chamber plants on pyrites. About three-fourths of our pyrites were then imported, the major portion coming from Spain, the rest from Portugal and Canada. Most of the sulfur then used in this country went to the sulfite pulp industry. Consumption in agricultural insecticides and fungicides and in rubber factories for vulcanization was steadily increasing. The quantity called for by manufacturers of chemicals and medicinals was insignificant.

By 1904, Union Sulphur was able to fill the American demand, and by cutting the Sicilian price of $24 a ton to $18, Frasch indicated plainly that he intended to do so.[5] When the Sicilian Consortium suggested pointedly that he had better stay out of Europe and give them a share of the American market, he replied by again reducing the price to $14 and appointing the aggressive, hard-boiled Herman Hoeckel his foreign agent.

Hoeckel, a German of the Prussian type, not only handled Union Sulphur sales, but acted as preliminary negotiator with the Sicilians. He built the sulfur refinery at Marseilles and so faithfully followed Frasch's instructions that it be big and substantial—to counteract Italian propaganda that the Louisiana deposits were small and that Union would shortly be unable to supply its customers—that when the war broke out he was charged by the French with being a German secret agent who had built an embryo fortress right within one of their key ports. The terrified Hoeckel disappeared and, so far as the chemical industry is concerned, vanished forever.

By 1907, the Sicilians were happy to agree to an international price based upon $22 a long ton, c.i.f. New York, and to concede a third of the European market to the Americans.[6] In 1912, unexpected complications nullified these amicable arrangements.

Governor Woodrow Wilson secured the passage of the famous "Five Sisters' Act," aimed to tighten the lenient New Jersey corporation laws, and the agreement between the Consortium and Union Sulphur (a New Jersey corporation) ran afoul some of its antimonopolistic provisions. By cable Frasch brusquely cut this embarrassing entanglement and characteristically adopted bold measures to forestall the consequences of a return to wide-open competition. He stepped up Union output from 205,066 tons in 1911 to 787,735 in 1912.[7] This was actually over 100,000 long tons more than the entire world consumption of 1911.[8] Having pretty well saturated American demand—then about 250,000 tons a year—sales abroad were pushed vigorously. Union Sulphur at this time maintained offices and warehouses at Harburg (near Hamburg), Rotterdam, Marseilles, and Cette, and during this eventful year added two new steamers to its fleet of freighters.[9] Although the 1912 exports more than doubled—57,736 long tons compared with 28,103 in

FRANCIS R. PEMBERTON

E. P. SWENSON

Chemical Industries

CLARENCE A. SNIDER

HOMER S. BURNS

1911—[10] the stockpile in Louisiana was increased nearly half a million tons.*

Frasch was girding the Union Company for war: not the World War, which he could not have foreseen, but a sulfur war. The Panama Canal had just opened, an opportunity for invasion of the West Coast and Oriental markets then held by Japanese volcanic sulfur.† His more immediate concern, however, was the prospect of stiff competition in the home territory. Since early 1912, Bryanmound, near the mouth of the Brazos River in Texas, had been the scene of unaccustomed industrial activity. Here, in defiance of Frasch's supplemental patents, a great hot-water mining plant was being hurried to completion, and on November 12, the first sulfur from a Texas dome flowed into the waiting vats. The Freeport Sulphur Company was in actual operation.

With a long bank account and a big stockpile, the Union Sulphur Company, led by a determined, daring president, was poised for battle on three fronts. What might have happened is merely curious speculation, for two unexpected, unrelated events changed the picture as completely as if its face had been turned to the wall. On May 1, 1914, Herman Frasch died in Paris,[11] and a few months later the Kaiser's armies were moving swiftly upon the French capital. The competitive battle was transformed into a struggle for greater production. War demands here and from our Allies grabbed up every ton of sulfur that both Union and Freeport could pump to the surface, and Frasch's preparedness stockpile became literally a lifesaver to our munitions output.

A few months after hostilities ended, a third hot-water process plant—Texas Gulf Sulphur Company at Big Hill, Matagorda County—was ready to begin operations. Sulfur competition shifted from inter-company to inter-material, brimstone against pyrites. Bigger outlets for high-test sulfuric acid were opening up in the chemical and petroleum-refining fields. Again the sulfur picture was turned completely about.

During the first three years of the war, when supplying munitions to England and France was a dress rehearsal of our own war effort of 1917-18, sulfuric acid earned the right to its nickname, "the old war-horse of chemistry." The quantity of acid, 50° Bé. basis, made here increased from 3,575,000 short tons in 1913 to 6,300,000 in 1916.[12] In these same years our consumption of crude sulfur grew from 245,000 to 659,000 long tons ‡ and our consumption of pyrites from 1,191,930 long tons (850,592 imported) to 1,683,794 (1,244,662 imported).[13] No actual, acute shortage of these sulfur-bearing materials developed prior

---

* Japanese production in 1912 was 53,692 long tons. (See Haynes, *Stone That Burns*, p. 316.)

† For U. S. sulfur statistics, see Appendixes XXXIII and XXXIV.

‡ Sulfur consumption in U. S., from various sources, is given in Appendix XXXIV.

to our entry into the war. It was clear, however, that any considerable further expansion of chemical manufacturing, especially of explosives, would create a critical, sulfur raw-material situation.

Even in these early stages, brimstone was clearly the chief beneficiary of war conditions, an unexpected twist in the trend which had been sharply favorable to its competitor. Indeed, in 1913, technical advances had scored rather heavily for pyrites. Profitable employment of the cinder from pyrite burners as a source of iron was begun by several plants. Most notable was a big installation at Roanoke, Virginia, by the Pyrites Company, Ltd., an affiliate of interests controlling the famous Rio Tinto mines in Spain, the largest shippers of pyrites to this country.[14] Furthermore, pyrites began to edge into the sulfite-pulp plants, where previously brimstone held an undisputed place. Improvements in the design of pyrite burners and the example of German and Swedish practices encouraged this switch,[15] which jeopardized sulfur's largest single domestic market. Finally, two new desulfurizing processes promised to create a worthy competitor for both pyrites and sulfur.[16]

At the Penn Mining Company refinery, Campo Seco, California, the Thiogen process [17] had been worked over to practical commercial operation, while the Hall process [18] was being installed and tested at the Coram, California, plant of the First National Copper Company. In 1911, the recovery of sulfuric acid from zinc and copper smelters passed the 100,000-ton mark and two years later it reached the rather impressive total of 149,000. Stimulated by war demands, it touched the all-time high record of 352,000 tons in 1917. But the true peak of smelter by-product acid's contribution to the national total was reached in 1914, when it was 20 per cent or more than the output from domestic pyrites, and nearly seven times greater than that from brimstone. Since the outbreak of the war, however, the percentage of this by-product acid dwindled to but a tenth of the total.[19]

Initially, the impetus to a greater use of sulfur came to our acid makers from explosives manufacturers who needed strong acid. By adding sulfur to the pyrites charge of the burners, they not only stepped up production, but also simplified and cheapened concentration operations. While such domestic pyrites consumption during the 1914-16 period advanced from 1,363,279 to 1,683,794 tons, and imports from 1,026,617 to 1,244,622 tons, after these dates, despite the added demands of our participation in the war, the total of either was not again equaled.* With the statistics before us, we can now see the wartime picture quite clearly. In the thick of hostilities, although the objectives were plain enough, the details of supply were highly confusing.

---

* For pyrites statistics, see Appendix XXXII.

Early in March 1917, Charles H. MacDowell of the Defense Council and Van H. Manning of the Bureau of Mines conferred on the serious shortage of pyrites caused by submarine sinkings and the shipping shortage.[20] All possibilities of increasing the domestic supply of sulfur-bearing materials were explored. The most obvious was to increase the output of the Virginia and Georgia pyrites mines.

Some Ohio Valley acid manufacturers were using a small tonnage of coal brasses (marcasite) which they were hand-cleaning and blending with foreign ores. The price they were offering was not attractive enough to warrant coal companies to mine the marginal seams containing the bulk of this material and to keep it separate from their run of mine output. The ore they did get was hand-picked from the waste piles. The attached coal increased temperatures, diluted the gas with CO_2, and decreased yields. It was decided, however, to look further into the matter and study washing and sorting methods. The possibility of blending some pyrrhotite with other ores was discussed, and it was agreed to make a test on 100 tons of ore. Heap-leaching pyrrhotite for the recovery of copper, a practice followed with Rio Tinto ores, and burning the leached fines, or roasting the ore in Wedge-type muffle furnaces were both studied, for there were large known deposits of pyrrhotite. Metal mines in the Rocky Mountain region might contain pyrites. The Duval County, Texas, surface deposits of sulfur were worth special study: burning the selected crude ore. The Louisiana-Texas sulfur mines should be inspected. Canadian output, going in large part to the General Chemical Company, might be increased. Mexico might be a source of supply. A large deposit of pyrites was known to exist near a West Coast Mexican port. Field investigators of the Bureau of Mines and the Geological Survey were instructed to investigate all of these possibilities.

Dr. William H. Nichols, president of General Chemical and then chairman of the chemical advisory group of the Council of National Defense, also anticipated a shortage of sulfur-bearing materials.[21] He knew the demand for acid would continue to grow. He suspected imports of Spanish pyrites would be further cut down. At the May 1917 meeting of his committee, he warned of a coming sulfur shortage, but neither in the industry nor in military circles did his logical deductions rouse a flicker of interest. Five weeks later we entered the war and the first step—an accurate chart of requirements—was then taken. It revealed a sulfur crisis.

Imports of pyrites from Spain were already falling off. Submarine activities and the demands on shipping were beginning to exert a pressure that became more severe. Domestic pyrites output was at its peak in 1916, due to a greater yield from old mines rather than to the opening up of new deposits,[22] nevertheless, labor and fuel shortages suggested that any further increase was improbable. What Nichols and MacDowell had foreseen was now painfully self-evident.

Providentially, the Bureau of Mines had by now completed its survey of available domestic sulfur sources, made by A. G. White,[23] and our acid plant capacity,[24] for the Raw Materials Division of the Defense Council, so that a factual basis for definite action was ready to hand. The study of marcasite, the sulfur-bearing impurity in bituminous coal of the Illinois-Kentucky fields, commonly called "coal brasses," had held some promise, but any hope of tapping this considerable supply was choked by the Fuel Administrator. Since the mines were not equipped to recover the brasses, he wisely refused to sanction any new, sideline activities that would detract from the maximum output of coal to meet what was a serious fuel shortage.[25] At the same time, Western native sulfur became suddenly very interesting to a number of optimistic speculators. The thin, uncertain character of these surface deposits was well known and the War Industries Board was reluctant to give priorities for sorely needed machinery to such distant, risky enterprises. However, a number of these Western properties did actually come into modest production.[26]

Out in West Texas also, a war-born boom blossomed in projects to recover the free sulfur in the vast gypsum beds of that region. Three companies were active: the Michigan Sulphur & Oil Company, the New Orleans Sulphur Company, and the West Texas Sulphur Company.[27] During the war all produced some sulfur, but by 1921 the strongest of them, West Texas Sulphur, closed down in the hands of a receiver.[28]

By the fall of 1917, Manning and MacDowell agreed that the sole source upon which they could rely for a large, dependable increase in supplies was the sulfur from the Gulf Coast salt domes; that present acid plants should eke out pyrites by burning an increasing percentage of brimstone; that any new government acid plants should be of the contact type equipped to burn sulfur.

Back in June 1917, the Chemical Committee, backed up by Baruch's Raw Materials Division, had negotiated a "fair price" deal with the Union Sulphur Company, by which it agreed to sell fertilizer manufacturers brimstone at $22 a long ton, f.o.b. mine. While the Freeport Sulphur Company did not formally subscribe to this agreement, it did adhere to its provisions. At the August 15 meeting of the Chemical Committee, a special committee—C. H. MacDowell, E. R. Grasselli, and Horace Bowker—was named to investigate domestic sulfur-bearing materials.[29] Two months later, a small committee of professional engineers, headed by J. Parke Channing,* was sent by Manning to investigate and report on the two Gulf Coast sulfur operations. This confidential report, dated New Orleans, November 4, 1917, confirmed the dependence of the country upon these two companies to meet the critical needs of the sulfuric acid makers. It summarized their operations as follows:

> Freeport has three plants with a total capacity of 23,800 horsepower maintained in operation constantly at from 150 to 175% of the rating, heating in all about 8,000,000 gallons of water for 24 hours, which is adequate for the steaming of six wells under ordinary circumstances, producing 1,500 tons of sulfur daily.
>
> Union has eight boiler plants with a total rated capacity of 21,480 boiler-horsepower, six plants with a rating of 16,230 boiler-horsepower, at present in use about 150% of rating, and heating some 8,000,000 gallons of water for 24 hours. Lower temperature for water is maintained at Union and seven wells in operation are producing 2,500 tons daily. Their plants are old and built on sunken ground and so it is considered unsafe to depend upon continuous operations. Construction of a new boiler plant requires about a year's time under favorable circumstances.†

In the meantime, the domestic pyrites situation was thoroughly explored and strenuous efforts were made to expand existing operations and open up new mines. The Geological Survey and the Bureau of Mines joined forces in a pyrites promotion campaign.[30] A special War Materials Committee, formed early in July 1917, and composed of representatives of mining and metallurgical groups, collaborated with them.‡ A war meeting on sulfur and pyrites was held by the New York Section of the American Institute of Mining & Metallurgical Engineers, August 23, at which A. G. White outlined the purpose of the Committee as being to locate and examine pyrites deposits and get them as soon as possible into commercial hands.[31] C. H. MacDowell of the War Industries Board pointed out the 150 per cent increase in the price of Spanish pyrites, which the Davison Chemical Company and the Pennsylvania Salt Manufacturing Company were importing;[32] and H. F. Wierum, in charge of the Balaklava Works of the Tennessee Copper Company, made a special plea that the present demand for sulfur be

---

* Channing, a mining engr. connected for years with Lewisohn interests, was pres. of the Tennessee Copper Co. (1903-8), where he introduced pyritic smelting and built the initial sulfuric acid plant. [See *Eng. Min. J. 111,* 61 (1921).]

† For a copy of this unpublished report, I am indebted to C. H. MacDowell. (W. H.)

‡ The organization meeting was held in Washington, July 12, with A. G. White, Bur. Mines, chairman; David White, Geol. Surv.; W. O. Hotchkiss, State Geol. of Wis., Nat. Res. Council, and Am. Assoc. State Geol.; and William Y. Westervelt of Ducktown Sulphur, Copper & Iron, Am. Inst. Min. Met. Engrs., and Min. Met. Soc. of Am. [See *Bull. Am. Inst. Min. Met. Engrs. 130,* v (Oct. 1917).]

utilized as an opportunity to develop both the Hall and the Thiogen processes.[33] W. Y. Westervelt offered sage advice: "I suggest . . . if you have an old gold mine east of the Mississippi River, anywhere near transportation, and it had pyrite in it, it will be worth while to look over your notes and see if there is a chance of working the property for pyrite instead of for gold." [34]

Domestic pyrites production increased in 1917 some 35 per cent over the prewar average, supplying that year almost a third of our greater requirements, against a quarter prewar. The larger output came chiefly from the expansion of old operations, and Virginia continued to be the leading producing state.[35] Here the Cabin Branch mine of the American Agricultural Chemical Company, the Arminium of the Grasselli Chemical Company, and the operations of the Sulphur Mining & Railroad Company and the General Chemical Company, were important contributors. Despite high prices and all the official promotion work, only two new, considerable operators appeared in this field: the American Sulphides Corporation, organized with a capital of $400,000.[36] A. T. Embrey, president, and L. B. Knox, secretary-treasurer, proposed to develop 600 acres in Virginia with a projected daily capacity of 150 tons. The Mammoth Mining Company—capital, $250,000; Emanuel Goodman, president; Wirt H. Miller, vice-president; D. M. Thomasson, secretary-treasurer; Thomas Marcom, manager [37]—acquired 300 acres of pyrites land at Hiram, Georgia.

The hesitancy of big capital to develop a number of likely pyrites properties uncovered by this official pyrites promotions campaign, indicated a rather nice appreciation of the growing strength of the sulfur-mining operations on the Gulf Coast, and of the implications of Horace Bowker's announcement, at the annual convention of the National Fertilizer Association,[38] calling upon all acid makers to change their plants over for burning brimstone. So rapidly did the supplies of pyrites, both imported and domestic, fall, that by autumn Southern plants reported stocks enough for only two or three months and a very rapid conversion to brimstone.[39]

Early in 1918, the prospects of sulfur materials supply degenerated critically. Imports of Spanish pyrites had dropped from 1,244,662 tons in 1916 to 967,340 in 1917. Domestic production had stepped up, but only from 439,132 long tons to 482,662. That Gulf Coast brimstone must be the main reliance to meet acid requirements of 9,000,000 short tons of 50° Bé. material, was becoming plainer day by day. Nevertheless, the War Industries Board made every effort to increase pyrites production, and on March 11, 1918, all domestic and Canadian producers were called to Washington.

From their optimistic reports, Arthur E. Wells of the Bureau of

Mines estimated a prospective output of 800,000 long tons of domestic pyrites and 400,000 long tons from Canada.[40] Within the month, due to shortages of labor in the domestic mines and of lake steamers to move the Canadian ore, these figures had to be revised downward to 600,000 and 200,000 long tons, respectively. To make matters worse, it was learned that the expected output of 1,100,000 tons of by-product acid from zinc-ore smelters would actually reach only 900,000 tons, because of restricted operations due to the low price of zinc. The climax was capped when the dire necessity for all available shipping to transport troops and munitions to France forced the War Trade Board, on May 6, to cut imports of Spanish pyrites to 125,000 tons between April 15 and October 1.

Rumors that the Government was to commandeer all sulfur and pyrites and operate the mines, itself, disturbed the industry.[41] The fire beneath this smoke was a report by William G. Woolfolk,* which had actually made this proposal for commandeering and suggested that a committee of the Chemical Alliance assume the difficult allocating burden.[42]

Unless executed by the Army as a war measure, such drastic action was beyond the powers of the War Industries Board. Following Baruch's well-known policy of cooperation with industry, the Chemical Alliance was requested to submit a concrete plan for the control and allocation of brimstone, pyrites, and coal brasses. The directors met at the Biltmore Hotel, New York, Friday morning, June 7, and after agreeing to submit such a plan, suggested that the details be worked out and executed by a committee. This would consist of three directors of the Chemical Alliance, a representative of the War Industries Board as chairman, W. W. Main, Assistant Secretary of Agriculture, with members of the Railroad Administration, Shipping Board, and War Trade Board as special consultants.[43] That same afternoon, over 250 producers and users of sulfur-bearing materials met in the Music Room of the Biltmore.[44] Horace Bowker reported the action of the Alliance, and after a long session of explanation and debate, the meeting approved this action.†

To serve on this Committee on Production-Distribution-Control of Sulfur Materials, quickly nicknamed the P-D-C Committee, the Chemi-

* Formerly Chicago mgr. of Sanderson & Porter, engrs. and contractors, and since Apr., chief of the Sulfur-Pyrites Section of the War Ind. Bd. Other members were: John R. Townsend, assoc. chief; Arthur E. Wells, Bur. Mines; Albert R. Brunker, chief of the Acids & Heavy Chemicals Section (pres., Liquid Carbonic Co., Chicago, and Atlantic Steel Casting Co., Chester, Pa.); Maj. W. H. Gelshenen, Army; C. K. McDonald, Navy; Maj. T. B. Archer, Marine Corps; and Lt. A. B. Baker, Ordnance Dept.

† Those attending this meeting are listed in Appendix XXXV.

cal Alliance named Augustus D. Ledoux, Warner D. Huntington, and Charles G. Wilson. From August 1 until December 3, this group had full charge of sulfur-bearing materials.[45]

This control of stocks of materials insufficient to satisfy all acid makers' wants was rigidly administered. Thanks to intimate knowledge of trade practices and requirements, and the cooperative spirit in which it was undertaken, this control called forth little grumbling. It solved the 1918 sulfur-materials problem. Attention was now focused on the Gulf Coast region as the sole hope of adequate sulfur supplies, should the war last another year.

Since the outbreak of hostilities, owners and promoters of salt-dome properties had been beseeching the Chemicals Division of the War Industries Board for financial assistance to develop sulfur deposits. A number of companies and syndicates had actually been launched. One of the most interesting of these was the American Sulphur Company, capital $12,000,000, backed by Charles G. Dawes, the Chicago banker and author of the famous Dawes Plan. This company was reported [46] to have acquired property adjacent to the Union Sulphur Company in Louisiana, but the large, steam-process plant projected never materialized. In the meantime, the Bureau of Mines quietly, in order not to stir up a swarm of speculators, investigated the known sulfur deposits and concluded the most promising prospect was the so-called Big Hill in Matagorda County, Texas. Manning, the Bureau's director, and MacDowell agreed that the plans already afoot to develop this property should be encouraged in every possible way.[47]

References

1. Haynes, *Stone That Burns*, pp. 3-45.
2. *Ibid.* p. 68.
3. *Ibid.* p. 69.
4. C. H. MacDowell, to author, Aug. 12, 1943.
5. Haynes, *op. cit.* p. 109.
6. *Ibid.* pp. 102-112.
7. R. H. Ridgway, Bur. Mines, *Inform. Circ. No. 6329*, 22 (1930).
8. *Eng. Min. J. 95*, 96 (1913); Haynes, *op. cit.* p. 316.
9. *Min. Ind. 1912*, 786.
10. Ridgway, *op. cit.* p. 48.
11. *J. Ind. Eng. Chem. 6*, 506 (1914); *Drug. Circ. 58*, 370 (1914); *O.P.D. Reptr.* 11 (May 11, 1914).
12. A. E. Wells and D. E. Fogg, Bur. Mines, *Bull. No. 184*, 6 (1920).
13. *Min. Res. 1913*, II, 34.
14. *J. Ind. Eng. Chem. 5*, 697 (1913).
15. F. M. Williams, *J. Soc. Chem. Ind. 32*, 457 (1913).
16. *Min. Res. 1913*, II, 31.
17. S. W. Young, *Eng. Min. J. 95*, 369 (1913).
18. W. A. Hall, *ibid. 96*, 35 (1913); H. F. Wierum, *Min. Sci. Press 109*, 518 (1914).
19. Kreps, *Economics of Sulfuric Acid Industry*, p. 105.
20. MacDowell, *op. cit.*
21. H. Bowker, address at meeting Acids Comm., Chem. Alliance, Atlantic City, Sept. 6, 1918. See *Comm. Acids Bull.* 10 (Sept. 13, 1918).
22. *Min. Res. 1916*, II, 419.
23. *O.P.D. Reptr.* 16 (May 21, 1917).
24. Wells and Fogg, *op. cit.* p. 8.
25. MacDowell, *op. cit.*
26. Wells and Fogg, *op. cit.* p. 33.

27. *Min. Ind. 1916*, 668; *1918*, 668; *O.P.D. Reptr.* 15 (June 4, 1917).
28. *Eng. Min. J. 112*, 869 (1921).
29. *O.P.D. Reptr.* 14 (Sept. 3, 1917).
30. *J. Ind. Eng. Chem. 9*, 815 (1917).
31. *Bull. Am. Inst. Min. Met. Engrs. 130*, xii (Oct. 1917).
32. *Ibid.* p. xv.
33. *Ibid.* p. xvii.
34. *Ibid.* p. xviii.
35. Tariff Comm., *Tariff Inform. Ser. No. 21*, 211-25 (1920).
36. *O.P.D. Reptr.* 22 (Nov. 19, 1917); *J. Ind. Eng. Chem. 9*, 1152 (1917).
37. *Drug Chem. Mkts.* 32 (Oct. 3, 1917).
38. *Ibid.* 5 (July 18, 1917).
39. *Ibid.* 15 (Sept. 19, 1917).
40. *Report on Supply of Raw Materials for Manufacturing Sulfuric Acid*, to L. L. Summers, War Ind. Bd., Mar. 14, 1918.
41. *Drug. Chem. Mkts.* 12 (May 29, 1918).
42. Rept. to C. H. MacDowell, dir. of Chemicals Div., War Ind. Bd., Apr. 15, 1918.
43. Chem. Alliance, *Spec. Bull.*, July 8, 1918.
44. *Drug Chem. Mkts.* 8 (June 12, 1918); *O.P.D. Reptr.* 29 (June 10, 1918).
45. *Chem. Met. Eng. 19*, 70 (1918); *Drug Chem. Mkts.* 7 (July 10, 1918); *Eng. Min. J. 107*, 70 (1919); *J. Ind. Eng. Chem. 10*, 656 (1918); *O.P.D. Reptr.* 89 (Dec. 16, 1918).
46. *Drug Chem. Mkts.* 30 (May 2, 1917).
47. Haynes, *op. cit.* p. 164.

Chapter 18

GULF COAST SULFUR

GULF COAST DOMES EXPLORED FOR OIL; SULFUR FOUND—FREEPORT SULPHUR BRINGS FIRST TEXAS DOME (BRYANMOUND) INTO PRODUCTION—GOVERNMENT PUSHES DEVELOPMENT OF BIG HILL BY TEXAS GULF SULPHUR—SULPHUR EXPORT ASSOCIATION FORMED —ACID MAKERS' CONVERSION TO SULFUR COMPLETE.

QUANTITIES, great quantities, of fresh water and cheap fuel are indispensable to the profitable operation of the hot-water system of mining sulfur. By making good the second of these economic requisites—hitherto unavailable in the swamps of southwestern Louisiana—the fountain of oil that poured forth at Spindletop, sixty miles away, assured the commercial future of Frasch's brilliant technical triumph. It was the first gusher in the East Texas oil fields, and the date of its strike, January 10, 1901, is a red-letter day in petroleum chronology. But if the famous Spindletop made American oil history, it completely rewrote the world's sulfur history.

Its discoverer, Captain Anthony Francis Lucas, was, in the language of Texas oil men, "one smart hombre." Son of an Austrian naval officer, Captain Francis Luchich, Lucas followed his father to the Polytechnic Institute at Gratz and the Naval Academy at Fiume. He was commissioned, but came to America to visit an uncle, upon whose advice he resigned from the Austrian Navy, Anglicized his name, and began putting his training in geology and engineering to work in exploiting American natural resources.[1] He gained considerable practical experience of the Gulf Coast region salt domes by operating salt mines among the Five Sister Islands of Louisiana.

There was then a big portion of luck in any great, new oil strike, but Lucas had been drilling the low mound of Spindletop near Beaumont, on the basis of a well-thought-out theory. He was convinced that these mysterious salt domes, thrusting up through the sedimentary deposits of the Gulf Coast region so that they form low mounds on the surface, were a sign of oil.* For two years he peddled this idea to

* At least, this is the story he afterwards told, but it may have been the wisdom of hindsight, for Wilber Judson, vice-pres. of Texas Gulf Sulphur Co., points out, "As a matter of fact, Lucas drilled into caprock at Spindletop, and according to all the information we have, was really drilling for sulfur." (Judson, to author, Aug. 13, 1943.)

anyone who might have enough money to finance his proposed drilling at Spindletop. He had scarcely gotten the fabulous flood of 100,000 barrels of oil a day under control, before he announced his intention of "punching a hole in every pimple on the Gulf Coast from the Mississippi to the Mexican border." Other adventurous wildcatters beat him to a number of these so-called domes, and during the next few years practically all of these prominent landmarks on the flat coastal plain were explored by drilling. Nobody ever struck another Spindletop. But in a number of these domes sufficient oil was found to rouse high hopes and eventually to make some profitable operations.

Recovered cores from some of the mound drillings showed unmistakable yellow signs of free native sulfur. A great deal of the dramatic early history of the American sulfur industry concerns the deliberate redrilling of likely domes to discover the one among scores that contained sufficient sulfur and was still of such geological structure that the hot-water process could be applied. Most of the domes were plastered with scores of titles, often conflicting and frequently leased and sub-leased for oil rights, all cut up in literally hundreds of tiny speculative "shoestrings." To acquire sulfur rights to such properties was a task to baffle a regiment of Philadelphia lawyers and to exasperate any conservative sulfur company treasurer.

During the life of the Frasch patents, when the Union Sulphur Company was in a monopoly position, many of these potential sulfur properties were offered to it. For the proverbial song, Frasch might have bought the sulfur rights to both Bryanmound and the Matagorda Big Hill, the two rich properties subsequently acquired by Freeport and Texas Gulf. He had a stock reply to all such proposals. "Gentlemen," he would say with crushing finality, "I am not interested. Nobody else can pump sulfur as we do, and in Louisiana we have all the sulfur we need for years and years. Someday, if I should ever want your property, I will buy it at grassland prices."

As the expiration of the Frasch patents approached, interest in various and sundry sulfur domes revived. During 1909-11, the whole Gulf Coast buzzed with rumors and the men who had so painfully and hopefully gathered up the mineral rights to several of the most promising properties began again to seek buyers. The recently organized fertilizer combinations, important drug interests in St. Louis, some well-known mining men, and a couple of prominent groups in Wall Street, all were attracted to the possibilities in sulfur mining.

The first Texas sulfur dome actually in production—Bryanmound, near the mouth of the Brazos River—had a long, romantic story.[2] On the west bank, between the mound and the Gulf of Mexico, was the old Spanish city of Quintana, once the most important Gulf port, whose decaying ruins were swept away by the hurricane and tidal wave of 1900. Here, in 1826, Stephen F. Austin landed the first 300 colonists he brought to the country. For this service the Mexican Government, among other rewards, granted him a tract of 177 acres on the dome. Between 1855 and 1861 W. J. Bryan acquired these 177 acres from the Austin heirs, and by 1887 the Bryan family had bought up 4,300 additional acres and owned about three-fourths of the mound area under which the then unsuspected sulfur-bearing strata lay.

In his "pimple-punching campaign," Lucas drilled two test wells in Bryanmound during late 1901. His first well ran into a heavy flow of hydrogen sulfide gas—strong presumptive evidence of sulfur in which he was not at all interested—and the second proved to be dry. Accordingly, the Guffy-Lucas team filed quit claims to the 1,416 acres they had under oil leases and abandoned the dome.[8] Seven other wildcat holes were drilled. None struck oil, but several turned up strong showings of sulfur.

In 1906, Henry T. Staiti bought up some mineral leases controlling part of the Bryanmound area, deliberately to exploit the sulfur. He interested George Hamman, a Houston banker, who in turn interested Edward Simms, the successful oil operator. Simms secured from the Texas Company an advance of $100,000 against royalties to explore the dome. Again no petroleum was found, but there were more indications of sulfur. The Texas Company withdrew, saying that it was in the oil, not the sulfur business, but Simms and his friends had greater faith. They organized the Gulf Development Company, to take over their leases and continue core-drilling. In all, they drilled 27 test wells and were so encouraged that, in 1908, they began actually buying land on the dome area.

In the meantime Simms and Hamman were busily trying either to finance a sulfur-mining company or to sell their rights and land advantageously. They were not very successful until during the winter of 1909, when Francis R. Pemberton appeared in Houston. Pemberton was inspecting lumber properties, but having visited the Union operation in Louisiana, he became most enthusiastic about sulfur possibilities. He had excellent connections with important northern financial interests, and being a personal friend of William T. Tires of the Union Sulphur Company and of George T. Lewis, "father of the Penn Salt Company," and also having had a finger in some of the fertilizer mergers, he was able to appreciate these chemical possibilities. He left Texas with an informal option on the Bryanmound property in his pocket.

Pemberton went straight to his fertilizer friends in Charleston and Richmond. They were interested, but a sulfur-mining proposition involved so much money that they were paradoxically fearful lest the expiration of the Frasch patents would see a stampede to the new industry and a grievous overproduction with ruinous price-cutting. Sidell Tilghman of the fertilizer group took Pemberton to Bernard M. Baruch in New York, and this shrewd financier, with wide mining experience, was immediately interested. He called in the distinguished mining engineer, Seeley W. Mudd, and sent him and Pemberton back to Houston: the first to appraise the sulfur deposit, the latter to get his option in good legal form and upon better terms. In anticipation of a successful deal, Baruch informally organized the Brazos Syndicate among a few of his friends and business associates.

This deal was never consummated. After a fascinating bout of wits between two able, experienced negotiators, the smooth, persuasive Pemberton and the hard-boiled, dominating Simms, terms were tentatively agreed. But the appraisal of Mudd and his assistant, Spencer Browne, concluded that "the Bryan deposit is good but spotty." The Bryanmound formation had demonstrated one of the initial hazards of sulfur mining, the difficulty of securing truly representative sample cores, for the limestone is all fissured and the friable sulfur is easily washed away by the drilling water or underground flows. Browne devised an ingenious return-flow drilling system which brought both water and cuttings back through the inside of the drill pipe, so as to make a satisfactory recovery for analysis.

After receiving this report Baruch himself went down to Houston, but he and Simms failed to agree upon a price. The Brazos Syndicate then disbanded, although Baruch, Mudd, and Browne did not entirely drop their interest in sulfur. Pemberton and Tilghman continued, however, to promote the Bryanmound property very actively. Among others in New York they called upon General Samuel McRoberts, vice-president of the National City Bank, and as a matter touching Texas, McRoberts turned them over to his fellow director, Eric P. Swenson. This forceful and energetic Texan * was immediately interested and set to work personally to organize what was shortly to become the Freeport Sulphur Company.

After a careful investigation, Swenson, having completed his financial arrangements, went to Houston, and November 6, 1911, S. M. Swenson

---

* His father, S. M. Swenson, went to Texas in 1838, a penniless young Swedish immigrant, who became one of the state's greatest landowners, friend and banker of Sam Houston. The son went to Trinity Coll. and stayed North in the banking business, eventually becoming chairman of the National City Bank, N. Y., but always retaining his affection for, and interest in, Texas. Typical of this interest, the sulfur mine near the mouth of the Brazos River appealed to him strongly as an opportunity to revive this port—hence the name—and he was much concerned with the development of the harbor and townsite of Freeport. Swenson died, Aug. 14, 1945.

& Sons secured from the Simms-Staiti-Hamman group a 30-day option on some 10,000 acres on, or adjacent to, Bryanmound. This option covered all but 15 of the 800 acres of the sulfur-bearing area. It included also much land between the dome and the river and along the river where Swenson visualized a future city. Its terms provided for a cash payment of $400,000; the erection of a plant for the extraction of sulfur before June 1, 1913; and royalties of $1.75 a ton on the first 200,000 tons extracted and 75¢ a ton thereafter.[4] Simms and his associates pooled their interests in equal thirds in the American Sulphur Royalty Company, and the Swenson firm turned its option over to the Vanderlip-Swenson-Tilghman Syndicate. The Syndicate was named for its three active managers, Swenson having associated with him Frank Vanderlip, also of the National City Bank, and Sidell Tilghman of the Richmond fertilizer group.*

Building the Bryanmound plant against time—the purchase contract called for sulfur production before June 1, 1913—was accomplished in the face of unusual difficulties. The dome is on the west bank of the Brazos. All transportation facilities terminated at the tiny town of Velasco across the river. These consisted of a single-track rail line which, thanks to the hurricane of 1909, was in shocking repair, and an old barge canal formerly used to carry rice and sugar to Galveston. From Velasco, every bag of cement and the last nail had to cross the river on a dilapidated, rope-cable ferry and then be hauled three miles to the plantsite. To keep out the high tides, a six-foot levee was thrown up along the river bank. Docks and tanks had to be built to handle the fuel oil from Mexico. To provide water for the Frasch operation, a ten-foot canal had to be dug from the Brazos to a big reservoir. All these facilities had to be provided while the four, 750-horsepower boilers, the pumps and air compressors were being erected and three wells for steaming were being drilled. Even the drilling was difficult, due to quantities of hydrogen sulfide gas which raised havoc with the eyes and noses of the drilling crews. All work was continually handicapped by a chronic shortage of experienced, dependable labor. Yet in spite of all these difficulties the job was completed ahead of schedule, and the mine was ready for steaming November 12, 1912.†

---

* The original underwriters were F. A. Vanderlip, S. M. Swenson & Sons, F. B. & S. Tilghman, James Stillman, Samuel McRoberts, John L. Williams & Sons, F. Q. Brown, Edwin Hawley, Williams & Peters, E. K. Knapp, E. M. Carter, Sidney Shepard, Benjamin Andrews, James M. Edwards, Orne Wilson, W. B. Chisolm, W. O. Wetherbee, John N. Steel, John Hays Hammond, A. Chester Beatty, A. C. Swenson, F. A. Fearing, George C. Reiter, and S. M. Betts. The amount subscribed was $700,000. (See Haynes, *Stone That Burns*, pp. 126, 290.)

† Contractors were Westinghouse, Church & Kerr, represented by Homer S. Burns, who later joined the Freeport staff, in charge of subsequent building operations. Ben Andrews, who formerly worked for Frasch in Louisiana, supplied the initial, practical

It would have been miraculous, indeed, if the initial operation of a new process of this sort, planned and operated on secondhand data, had not encountered difficulties. As a matter of fact, much subsequent experience with hot-water mining has demonstrated that, due to peculiarities of the physical structure of the domes, each individual operation invariably presents a new set of problems.[5] At Bryanmound, most of 1913 was therefore spent in experimenting, and it was finally concluded that additional hot-water capacity was essential to efficient production. Accordingly, a duplicate of the original power plant was begun and most opportunely was ready in September 1914, just after the outbreak of the war in Europe. Output jumped from 10,504 tons in 1913 to 41,872 tons in 1915.* Freeport was all set and ready to take advantage of the enormously increased demand for brimstone.

At the very time that, in recognition of his discovery, Herman Frasch was being awarded the coveted Perkin medal,[6] this first competitor of Union Sulphur appeared on the scene. Frasch received favorably royalty proposals from Swenson and Vanderlip for the right to use his process, although the basic patents had expired, but he died before these negotiations were completed. In the following November, after the Bryanmound operation was in smooth production and the threat of its competition had become very real, his successors entered suit based on the contention that the Frasch process could not be practically worked without infringing patents covering certain modifications and improvements made by Frasch, and still in effect. In May 1918, the United States District Court of Delaware sustained these claims.[7]

Union immediately offered Freeport use of its patents for the duration of the war, announcing that it preferred to take chances on collecting reasonable damages and royalties later, rather than to impede in any way the war effort.[8] This patriotic gesture offset in a measure a good deal of undercurrent criticism of the Union management which had had difficulty with the War Industries Board in adjusting an agreed price for sulfur.† Frasch's German birth had roused suspicions of his loyalty, and the Company was accused of not cooperating cordially with the Government. This was given as one of the reasons for the

know-how. He resigned Oct. 1, 1913, and was succeeded by C. A. Jones, formerly manager of the Swenson properties in west Texas. Under Jones, Absalom Webber, an experienced oil driller, was in charge of mining and P. George Maercky was general administrator.

* Figures supplied by Freeport Sulphur Co.

† The prewar price of sulfur was $20 a long ton, f.o.b. mine, and the price agreed for sale to sulfuric acid and fertilizer makers was $22. The open-market price was $26.50 at the mine; in the black market the price reached $40. Pyrites producers continually complained that sulfur prices had not risen proportionately to other commodities, and in competition with their material, did not hold forth to them sufficient inducement to increase domestic production by opening up new properties.

drastic control over all sulfur and pyrites supplies which the War Industries Board established July 9, 1918.[9]

As early as 1911 the Union mine in Louisiana gave indications of increasing operating difficulties. The flow of sulfur dwindled, then stopped, and was restored only after the excess of cold ground water was drawn off by bleed pumps. This became standard practice, and the cold water thus removed amounted to as much as 9,000,000 gallons a day. By 1914, subsidence of the mound surface reached twenty feet in some places and required constant reinforcement of the foundations of the boiler house and other buildings.[10] Although the J. Parke Channing confidential report to the Bureau of Mines, December 17, 1917, estimated that the 1917 reserves still amounted to 4,706,000 long tons, against 2,675,000 at Bryanmound,* nevertheless production was becoming constantly more expensive.

August 6, 1918, a cyclone swept across the mine area, ripping off roofs, crashing the forest of tall wooden derricks into a gigantic pile of jackstraws.[11] This disaster completely shut down the mine. It had come at a fortunate time, however, following a couple of months of top output, when the stockpile was large. In the end it proved to be a well-disguised blessing. The boilers and heavy machinery were virtually unharmed, and the wreck of the derricks and buildings forced a revamping of the entire layout, making it possible to readjust so as to offset the subsidence. By working day and night, a miracle of reconstruction was accomplished, and at the end of three weeks some wells were pumping again. Full production was restored within two months. There was no more malicious gossip about the lack of cooperation of the Union Sulphur Company in our war effort.

Channing's report had pointed out that Union and Freeport were consuming, each, about 4,000 barrels of fuel oil a day, all of Freeport's and part of Union's supply coming from Mexico, and that they were at least conceivably vulnerable to submarine attack. The Army recognized the dangerous location of Freeport right on the Gulf Coast, and General Pershing, immediately after the declaration of war, authorized military protection for this vital plant.

Channing had estimated that while in the next five years the two companies would produce a total of 6,200,000 tons—4,200,000 from Union, 2,000,000 from Freeport—their combined output for 1918 would not exceed 1,400,000 tons. He concluded that brimstone from the Gulf Coast region, extracted by the Frasch process, was the sole

---

* It is an interesting commentary on the accuracy of such estimates that between 1895 and 1924, when it was closed down, Union's Sulphur Mine produced 9,500,000 long tons. Freeport's Bryanmound, during its producing life of about 22 years, yielded 5,000,000.

prospective supply adequate to solve the country's sulfur-supply problem. Other men, as we know, had already reached this conclusion.

While Baruch and Simms were trying to come to terms over the Bryanmound property, back in 1909, Spencer Browne, the clever mining engineer who had sampled that dome, visited another prospective sulfur property. Big Hill[12] in Matagorda County—80 miles southwest of Houston—like Bryanmound, had been explored for oil shortly after the Spindletop gusher. A similar flow of hydrogen sulfide gas was encountered and moderate quantities of oil, but in the autumn of 1904, salt water suddenly drowned out the fifteen small wells operating there at the time. Some deep wells had turned up conspicuous cuttings of sulfur, and in 1908 two St. Louisans, A. C. Einstein and John W. Harrison, having come to Texas deliberately to hunt for sulfur deposits, drove a test well on the northeast slope of the Matagorda dome. Their showing was so favorable that they interested Theodore F. Meyer, president of the Meyer Brothers Drug Company, and the group organized the Gulf Sulphur Company.* They owned only some 200 acres of a dome 4,000 feet long and 2,400 feet wide, but these were in a thick sulfur-bearing sector, and the new test wells drilled by their engineer, Dr. George S. Hassenbruch, seemed fabulously rich.

It was at this time that Spencer Browne, scouting for likely sulfur domes, turned up at Big Hill. Despite the promising showing, the Gulf group had about decided that they could not swing the proposition financially. They found drilling more costly than they anticipated, and a Frasch plant would run into a couple of million dollars, with the then uncertain prospect of a disastrous patent suit. Knowing that Browne was associated with Mudd, who was consultant to Bernard Baruch and other important financial interests, they welcomed the opportunity to interest more capital.

Browne was deeply impressed with Big Hill and did not hesitate to express the opinion that it was more promising than Bryanmound. More than this, after the Baruch-Simms negotiations fell through, he brought Einstein and Allen to Baruch in New York. Although nothing materialized at the time, he and Seeley Mudd kept in touch with the St. Louis people. In 1916, the Freeport operation having been successfully launched and the war demand for sulfur being insistent, Mudd easily revived Baruch's interest in Big Hill. Together they approached J. P. Morgan. Morgan consulted his mining confidant, Colonel Wil-

---

* Incorporated for $250,000 by Einstein, Harrison, Meyer, and J. M. Allen of St. Louis, E. B. Pickett of Liberty, Tex., John S. Sunderland and John M. Corbett of Bay City, R. O. Middlebrook and Hugo Spitzer of Matagorda, the last four being landowners on the dome.

liam Boyce Thompson, and acting on his recommendation, agreed to take part in financing the Big Hill project.

Mudd and Baruch had bought control of the Gulf Sulphur Company, though the original backers still held a minority interest. Acting through the corporation, whose capital was increased to $500,000, they undertook serious exploration of the dome and at the same time began quietly to acquire land. Having been exploited as oil property, Big Hill acreage was highly subdivided, and to make the task harder several wide-awake operators in oil leases had got control of some 650 of the dome's 3,125 acres which they held for a neat profit. Though Browne's reverse-flow cores were exceedingly encouraging, it was determined to make haste slowly, so as to obtain complete control of the dome as economically as possible. The Texas Gulf Sulphur Company, under which Gulf Sulphur had been reorganized with a capital increase to $5,000,000, had 409 separate legal instruments to acquire this property. It was also planned to start on a modest scale—a 4,000-horsepower boiler plant—so as to try out the process and also to ease into the sulfur market, which apparently was going to be liberally oversupplied with three producers in the field. The war changed all these plans.

Mudd resigned the presidency of Texas Gulf Sulphur to enter war work, and he was replaced by Walter H. Aldridge,* chief engineer on the staff of Colonel Thompson. Baruch went to Washington as head of the War Industries Board. Browne followed his chief into the Army, and his assistant in the field, W. T. Lundy, did the same. Despite this stripping of key personnel, when MacDowell and Manning urged that it was a patriotic duty to bring the Big Hill dome into production as quickly as possible, Aldridge agreed to develop the property without financial assistance from the Government.

But to build a new sulfur plant required many priorities, and according to the rule established by the War Industries Board, these could only be granted for plants built to fill contracts with our Government or Allies. Baruch, having a financial interest in the enterprise, refused flatly to have anything to do with either contracts or priorities for the Texas Gulf Sulphur Company. He told Aldridge that any sulfur sold our Government or the Allies during the war must be billed at cost. J. P. Morgan & Company were the official buying agents for the Allies, and E. R. Stettinius stood firmly on similar ground. He stated em-

---

* Aldridge was a leading, constructive figure in the development of American sulfur. He also made important contributions in other mining fields, having been at various times the managing dir. of the Consolidated Mining (Canada), the Inspiration, and Magma Copper companies, and for 14 years in charge of mining development work for the Canadian Pacific, when he established the famous smelters at Trail, B. C. Since 1918, he has been pres. of Texas Gulf. He was trained at the School of Mines, Columbia U., and his Alma Mater awarded him an hon. D.Sc. in 1929.

SEELEY W. MUDD

SPENCER C. BROWNE

WALTER H. ALDRIDGE

Chemical Industries

WILBER JUDSON

phatically that his house would countenance no Government or Allied contract unless either the Morgan interests were bought out of the sulfur project by their associates, or the price was set by the Federal Trade Commission. Accordingly, the offer to the Ordnance Department of the first 200-tons-a-day production up to 200,000 tons, at $20 a ton, was amended February 21, 1918, so that the price would be "as the Government may decide is fair and reasonable as compared to prices paid to the large sulfur producers of similar tonnages in the Louisiana-Texas Gulf district at the time." To prevent any suspicion of favoritism, even this offer was withdrawn. Priorities of the same rating as the other sulfur companies were obtained only because the Bureau of Mines insisted that another source of sulfur supply was vital, and through the active, personal intervention of C. H. MacDowell to Judge Edwin B. Parker, chairman of the Priorities Committee of the War Industries Board.

Construction at Big Hill began August 13, 1918, and the first well was steamed March 19, 1919. The work was directed by Charles Biesel, while prospecting work, which continued till the sulfur body was completely outlined, was done by H. E. Treichler. Big Hill, or Gulf, as the operation came to be known, proved to be a most fortunate dome. Based on yields at Sulphur Mine and Bryanmound, the original boiler installation at Gulf was expected to produce 1,000 tons of molten sulfur in 24 hours. After three years' working experience, it pumped up 4,000 tons daily. This exceptional thermal efficiency was achieved chiefly because the internal structure of the dome was almost ideal for the Frasch process. The Union dome lacked a sufficiently thick, tight blanket of gumbo over the caprock, and Bryanmound was handicapped by the fissurous character of the caprock and considerable quantities of cold ground water. The Gulf caprock was only 300 acres in extent, but the sulfur horizon beneath averaged 60 feet in depth, a concentration of the deposit that also made for favorable working conditions. During its active life of 23 years, this dome produced 12,350,000 tons of sulfur.[13]

In September 1919, six months after the Gulf plant first produced, a tropical hurricane swept all but one of its 30 wooden drilling derricks into a tangled jumble of splintered beams and twisted piping. Production was out for a week, and it took months to restore all wells, since the wreck of a derrick almost invariably snapped off the piping. June 21, 1921, another hurricane ravaged the plants of both Freeport and Texas Gulf.[14] Out of these disasters rose the steel derrick, now used in all sulfur fields.

The lush flow of sulfur at Gulf threatened to swamp the market. It appeared at a highly critical juncture. The war was over and its exceptional demands dead. At the insistence of the War Industries Board, Union and Freeport had both built up enormous stockpiles, a total of over 2,000,000 tons, an 8-year supply for the normal prewar domestic demand.

By taking advantage of the switch from pyrites to brimstone, which had been forced upon the sulfuric acid makers, particularly the big fertilizer companies, Texas Gulf sold its sulfur without being forced to cut its way into existing markets. The trend was set favorably in this direction.[15] There was an increasing demand for strong acid created by the diverse expansion of the chemical industry. During the war, the Government had done good missionary work for sulfur among the acid makers, and many of them had of necessity adapted their plants for sulfur burning. Once such change-overs were accomplished, the convenience of this material made a strong appeal to operating men and its economies impressed executives. A whole series of technical developments, within and without the acid industry, encouraged this switch. Finally, the direct uses of sulfur in rubber vulcanization (the tire industry expanded enormously at this time) and in agriculture (chiefly for lime-sulfur sprays and sulfur dusting) combined with these other factors materially to increase the consumption of sulfur in this country.*

Frasch, who had dominated the commercial policies of Union as well as its technical activities, had from the first adopted selling policies that were to serve the sulfur industry well in this period of stress. Union sold sulfur by the carload only and at a known, fixed price, quoted invariably f.o.b. mine. Large consumers were sold direct, but any chemical merchant or jobber could purchase in carlots on an equal basis. The producer left the less-than-carload market to them; established no selling agencies; made no effort to dictate prices. Accordingly, freight rates plus the dealer's profits, controlled by wide-open competition, set the local price of sulfur in small lots. Admittedly this market was not large, but the system Frasch maintained so rigidly put sulfur sales on a sound, known basis with a minimum of lost motion and friction in the trade and with the least possible selling effort on the part of Union.

Freeport handled its domestic business through Parsons & Petit of New York, an old-established firm of chemical merchants. When E. P. Swenson decided thus to concentrate Freeport's energies on production, he was following a favorite method of the day and one that under the circumstances was undoubtedly prudent. Unlike Union, which had had no domestic competitor, Freeport had to sell in a well-established market, and initially at least, its sales must be made in great part to Union's customers. Parsons & Petit enjoyed a high reputation, and as former American agents for the Sicilian Consortium, they were thor-

---

* For detailed figures, see Appendix XXXIV.

oughly familiar with sulfur uses and buyers. When Texas Gulf came into the market, Walter H. Aldridge combined both methods. The well-known firm of H. J. Baker & Bro. were employed as selling agents, their activities having greatest success in the fertilizer field, whereas the sales department developed by Aldridge actively solicited other markets.

In the collapse of domestic business during 1920, all three companies assiduously cultivated foreign markets. Here they came into head-on competition with the government-backed Sicilian Cartel, whose position had been strengthened by the war and by the acquisition of 94 per cent of the sulfur on the Italian mainland by the Montecatini interests, largest chemical manufacturers of the country and staunch supporters of the Cartel.[16] At first Ernestino Santoro, head of the Consortium, decided to fight the American invasion, but in August 1922, at Geneva, he met with representatives of the three American companies to see if an equitable truce might be negotiated. Clarence A. Snider represented Union; E. P. Swenson, Freeport; and Wilber Judson, Texas Gulf. But the claims of the Italians to all the Continental market; their reluctance to include Montecatini in their agreement; and most serious of all, the inability of the three American firms to agree, brought this meeting to a futile ending. This last difficulty was to be solved by the Webb-Pomerene Act which permitted the American companies to act in concert through the medium of an export association.

In the meantime, in the American markets the competition of sulfur and pyrites was being gradually shaken down to a sound basis. Eventually the conflicting claims of any raw materials for chemical manufacture must be settled upon a cost basis: not only the actual cost of the materials themselves, but also all the comparative costs of their respective processing. So dominating is the acid maker in American sulfur consumption, that in the long run the price of brimstone is controlled by what he can afford to pay for this material in comparison with the prices of imported and domestic pyrites. The basis of this technological logic is made clear by reducing these competitive quotations to the basis of their values expressed in cents-per-unit of sulfur. These valuations, during this critical readjustment period, have been worked out by Edward H. Hempel.[17]

As his table indicates (page 218), the adjustment was not completed until 1926, but by 1922 it was pretty clear what the answer was to be. Sulfur had definitely replaced pyrites as the chief raw material of the American sulfuric acid industry.

By 1922 there were again signs of expansion of the Texas-Louisiana sulfur industry. Freeport, which had shut down its Bryanmound operation during the greater part of 1921,[18] was negotiating with the Texas Company a royalty lease of the sulfur rights at another dome,

YEAR		U. S. BRIMSTONE (f.o.b. mine)	IMPORTED PYRITES (BEST) (ex-vessel N.Y.)	U. S. PYRITES (f.o.b. mine)
1919	Jan.-June	18	17	15
	July-Dec.	15	17	...
1920	12 mos.	15 to 16	16.6	12.9
1921	12 mos.	15 to 16	14.25	10.6
1922	12 mos.	14	13	8.5
1923	12 mos.	13 to 14	12.25	8.8
1924	12 mos.	13 to 14	12	9.7
1925	Jan.-Apr.	13 to 14	12	...
	May-Aug.	15	13	9.3
	Sept.-Dec.	15 to 16	13	...
1926	12 mos.	18	13.5	9

Hoskins Mound.[19] At the same time Union, its Louisiana mine now showing plain signs of exhaustion, was drilling wells on Damon Mound. Though as yet in the trial stage, these activities showed, more than anything else could do, how firmly the new sulfur industry had established itself and with what confidence it faced the future.

REFERENCES

1. Haynes, *Stone That Burns*, pp. 47-52; R. S. McBeth, *Trans. Am. Inst. Min. Met. Engrs. 65*, 421 (1921).
2. Haynes, *op. cit.* pp. 116-34.
3. W. Kennedy, "Bryan Heights Salt Dome," in Moore, *Geology of Salt Dome Oil Fields*, p. 678.
4. Text of option, in Union Sulphur Co. *vs.* Freeport Sulphur Co., U. S. Circ. Court Appeals, 42d Circ., Oct. 1918, XI, p. 51 *seq.*
5. Haynes, *op. cit.* pp. 61-66.
6. *J. Ind. Eng. Chem. 4*, 131 (1912); *Met. Chem. Eng. 10*, 73 (1912).
7. *O.P.D. Reptr.* 27 (Apr. 22, 1918); 60C (July 15, 1918).
8. *Eng. Min. J. 106*, 1088 (1918).
9. *O.P.D. Reptr.* 27 (Apr. 22, 1918); 63 (July 15, 1918).
10. Haynes, *op. cit.* p. 146.
11. *Min. Ind. 1918*, 667.
12. Warner, *Texas Oil & Gas Since 1543*, pp. 117, 193, 218; A. G. Wolf, "Big Hill Salt Dome," in Moore, *op. cit.* pp. 691-717; Haynes, *op. cit.* Chap. 8.
13. Haynes, *op. cit.* p. 315.
14. *Min. Res. 1921*, II, 169.
15. Kreps, *Economics of Sulfuric Acid Industry*, p. 104.
16. C. Vannutelli, "Solfio," *L'industria mineraria* (Milan), 110 (1931).
17. Haynes, *op. cit.* p. 173.
18. *O.P.D. Reptr.* 24 (Apr. 4, 1921).
19. *Min. Ind. 1922*, 644.

Chapter 19

CRITICAL METALS

ELECTRIC FURNACE PLUS CHEMICAL CONTROL HASTEN DEVELOPMENT OF FERROALLOYS: TITANIUM, TUNGSTEN, MANGANESE, VANADIUM, ZIRCONIUM, CHROME—PIONEER WORK OF F. M. BECKET—WAR INDUSTRIES BOARD COMMANDEERS PLATINUM—AMERICAN MAGNESIUM RETAINS TWO SUPPORTERS POSTWAR.

TRADITIONALLY Mars is a willful, profligate customer of Vulcan, and having modernized his weapons, the old war god during the First World War inspired great advances in the industrial techniques of metallurgy. Indeed, the imperative and specialized demands of that conflict came at just the right time to quicken vigorously the development of alloy steels, then almost in its infancy. Furthermore, critical shortages compelled metallurgists to reappraise the properties of many metals.

Chemistry made notable contributions to the progress of this period, and the chemical industry was one of its chief beneficiaries. The chemical industry has a double stake in the metals: first, as raw materials, chiefly in the production of a host of metallic salts, and second, as construction materials for its apparatus and reaction vessels. This chapter deals with the latter employment of the metals.

The big, sudden expansion of chemical production in this country during the war had important, direct effects upon the American iron and steel industry at a crucial period. Until the convulsion of 1914, the astonishing growth of our iron and steel output had been a pell-mell race with demand. In the scramble to satisfy the country's rapidly increasing ability to consume, which began during the Civil War, the steelmakers had no time to research for new metallurgical processes or to experiment with improved products. Richly blessed in their raw materials—Connellsville coke of high purity and splendid physical structure with cheap, abundant, high-grade Lake Superior ore—they stuck to the job of doubling their tonnages every decade. Only one major technological revolution was forced upon them. By a lucky coincidence they were able to take this in their stride.

In the early days of feverish railway building, the demand had been all for Bessemer-steel rails. As time passed, however, engineers began expressing a marked preference for open-hearth steel. Fortunately this choice began seriously to affect the demand at an opportune moment. It was discovered that the Lake Superior deposits, far from being an inexhaustible supply of low-phosphorus ore suitable for the acid Bessemer process, actually contained far vaster quantities of ores well fitted to the requirements of basic open-hearth steel, yet not sufficiently high in phosphorus to be adaptable to the basic Bessemer operation so widely employed in Europe. Except for this comparatively painless transition from acid Bessemer to basic open-hearth steel, American steelmakers had been well content to borrow their technology from abroad, adopting promptly and ready-made any new developments of proved worth.[1]

The bold innovations of American steelmakers, and they were many, dealt with the size of their operations. They magnified the plans of their British and German teachers to gigantic scale, culminating, just prior to the outbreak of the war, in the installation of the largest electric furnace in the world. Not only because the explosive expansion of this electrical refining process was quite typical of the industry and the times, but also because it played a part in high-grade alloys, that the points of this story are significant. The initial American installation was made by the Halcomb Steel Company, Syracuse, New York, under the direction of Dr. John A. Mathews,* in 1908. From an open-hearth furnace the liquid steel was transferred to the electrical unit for deoxidation, desulfurizing, and other refining modifications.[2] So quick was the adoption of this idea, that in 1915 the electric-furnace output was 450,000 tons annually, an increase of 100 per cent over the previous year—the greatest national production in the world. Two years later, the Illinois Steel Company installed three, 30-ton electric furnaces with a capacity of 200,000 tons of carbon and alloy ingots a year,[3] and in 1920 there were in the United States 356 such installations, a greater number than the combined total of England, France, and Germany.[4] When the government ordnance plant at Charleston, West Virginia, was started in 1921, it put into successful operation the two largest electric-steel furnaces built up to that time, each with a capacity of 50 tons per charge.[5]

A long string of similar superlatives, characterizing every phase of our iron and steel industries from mining to rolling, were substantiated by the statistics.† The plain fact that the United States produced and

---

* Mathews, one of the most successful, practical metallurgists of his day, did post-graduate work at Columbia and the Royal School of Mines, London, having won the Carnegie and Barnard research fellowships. He received the first award of the Carnegie gold medal for research from the Iron & Steel Inst., and the Hunt medal of the Am. Inst. Min. & Met. Engrs. At the time of this installation, he was general mgr. of the Halcomb Co., becoming pres. in 1915, and in 1920 vice-pres. in charge of research, of the Crucible Steel Co. He died Jan. 11, 1935.

† Appendix XXXVI gives salient figures of ore, steel, and alloys production and prices, 1912-22.

Engineering & Mining Journal

JOHN A. MATHEWS

AUGUSTE J. ROSSI

Industrial & Engineering Chemistry

WILLIAM D. COOLIDGE

WILLIAM F. MEREDITH

consumed more steel than any other country—as much, indeed, as 40 per cent of the world total—was frequently cited as boastful, but reliable evidence of our industrial progress and strength. It was therefore a great shock to discover that even our rich resources and enormous furnaces and fabricating capacities were unable to meet the demands of the war. The shortness of the public memory and the exorbitant demands of modern technological war on materials were both emphasized during World War II by the same surprise that our greatly increased capacity for steel, and indeed all metals, again proved inadequate.

No doubt the strenuous effort to fill war orders during 1914-18 handicapped immediate metallurgical progress, although paradoxically the production battle did help the rapid expansion of the electric furnace and did stimulate the development of alloys. In the stress of the war effort, it was learned that acid open-hearth steel, requiring 13 to 15 hours for a 50-ton heat, could be replaced in ordnance by basic electric steel made in much less time.[6] The new demands of the chemical industry for steels resistant to all types of corrosion and able to handle the extremely high pressures of the synthetic-ammonia process, were war needs that simply had to be satisfied.

The year 1912 has been set by Bradley Stoughton * as marking the beginning of the American iron and steel industry's serious interest in the scientific improvement of its products, reflected in many careful chemical studies.[7] Indicative of this interest, the Bethlehem Steel Corporation spent $75,000 in 1913, in building and equipping what was then the largest chemical and physical laboratory in the industry.[8] Two years later, in a symposium on the chemist's contributions to the steel industry,[9] Allerton Cushman, founder of the Institute for Industrial Research, one of the first of the cooperative research organizations, and George W. Sargent, vice-president of the Crucible Steel Company, technologist and executive, agreed: that exact analytical data were now available on all principal types—ore, iron, slag, steel, coke, furnace gases, refractories, and alloying materials; that quick, simple methods of analysis had been devised to assure chemical control of every important step in steelmaking; that both physical and organic chemistry were widely used in metallurgical researches; that the chemist was to be credited with the development of alloy steels and that he would determine the future course of the industry.

This rather sudden interest in chemistry was not a spontaneous growth. It had commercial roots. During the last quarter of the nineteenth century ships were changing from wind to steam, from wood

---

* At that time in private consulting practice, Stoughton was later head of the Metals Div. of the Nat. Res. Council, and after the war prof. met. at Lehigh.

to steel. Coming just when railroad building was slowing down, the building of our Spanish War battleships was a strong, timely impetus to alloy-steel developments. Armor plate, face-hardened by Henry A. Harvey's process, was replaced about 1890 by the improved armament steels first developed at the Creusot Works in France and later perfected by the Krupps in Germany. These were nickel-chrome alloys which we must either import at a fancy price or produce for the ambitious program we had undertaken to modernize the American Navy. This provided a logical, economic reason for the Willson Aluminum Company * which turned to copper, aluminum, chrome, and other alloy-steel ingredients when its original aluminum process proved impractical. At the turn of the century, the researches of Taylor of Bethlehem Steel on high-speed steel had important effects upon both alloy steel and the machine-tool industry.

About this time, titanium-carbon steels, then produced in greater quantities than all other alloy steels, suffered a very marked eclipse.[10] Declining use of Bessemer steel in rail making raised questions as to the actual value of the titanium alloy for this purpose, which in turn stimulated experiments with other alloys and their comparison for a number of specific uses. Among the first fruits of these activities was the introduction of Mayari steel produced from natural alloys from Cuban ores containing small proportions of nickel and chromium, and the use of copper as an additive to steel.[11]

The principal sources of titanium, both for ferrotitanium and the various chemical salts of this metal, were rutile, ilmenite, and various titaniferous ores. Commercial deposits of rutile within the United States were centered in Virginia, and although the General Electric Company had entered this field in 1907, it had abandoned the enterprise shortly before the outbreak of the war.[12] The American Rutile Company, which had begun operations in 1900, was left as the sole domestic producer. Most of the ilmenite was imported from Quebec. Just before the war, J. T. Singewold investigated the economic value of the titaniferous ores of the country and concluded that their importance as a factor in our ore resources was greatly exaggerated.[13] In the face of this appraisal, on February 3, 1914, the MacIntyre Iron Company began an experimental smelting of titaniferous ores in the Cedar Point furnace of the Northern Iron Company, at Port Henry, New York. The project, which was in charge of F. E. Bachman, was to exploit the largest and richest known deposit of this mineral in the Adirondack region, but smelting difficulties were encountered and the experiment was abandoned.[14]

---

* Later a part of the Electro Metallurgical Co. and the Union Carbide & Carbon Corp.

During the war, transportation difficulties so reduced the imports of ilmenite from Quebec that its recovery and that of rutile from the beach sands of Florida was undertaken by Buckman & Pritchard, Inc.[15] A plant was built; a modest production achieved in 1917; and special attention was devoted to the recovery of rutile, which was found associated with the ilmenite, all because of the military demand for the manufacture of smoke screens. So important was this demand that, in April 1918, the Bureau of Mines sent an investigator to study the rutile properties both of this new company in Florida and of the American Rutile Company in Virginia. Before his report was made, however, the Army awarded a contract to Buckman & Pritchard for 410 tons of rutile at $90 a ton, making an advance payment of $11,000 to speed production. No delivery was made before the Armistice, but the production coming in shortly afterwards was sold for 1918 and 1919 to the General Electric Company. Buckman & Pritchard had a large investment in a plant for the electrostatic separation of the rutile, and in 1919 they applied to the Board of Contract Adjustment for relief to cover their losses on the canceled government contract. This award was adjusted by deducting the advance payment plus interest, and the enterprise was forthwith abandoned. Again the American Rutile Company, now a subsidiary of the Metal & Thermit Corporation, was left the only American producer of titanium minerals.[16]

Although titanium had slipped from its first place among steel alloys, its use expanded during the war, particularly in steel for galvanizing and tin plating. In 1917, the estimated tonnage of titanium-treated steel reached 2,000,000 tons,[17] and that year Dr. Auguste J. Rossi was awarded the Perkin medal for his conspicuous work in establishing titanium as a commercial metal, against the strong prejudices of old-time steelmakers. He had demonstrated that titanium, far from being injurious, actually improved certain properties of steel. He was thus the father of alloy steels in this country.[18]

At this time, there were two producers of ferrotitanium in the country. The Titanium Alloy Manufacturing Company operated at Niagara Falls, feeding its electric furnaces with ilmenite from Quebec and producing both the carbonless and ferro-carbon types. After the German-owned Goldschmidt Thermit Company was taken over by the Alien Property Custodian, it was sold to American interests who changed its name to the Metal & Thermit Corporation. It produced a ferrotitanium containing aluminum, and there were lively technical debates as to the comparative merits of carbon and aluminum as deoxygenizer.[19]

It was in its chemical uses, however, that titanium scored its best gains. War shortages of dyes and mordants prompted new and greater use of titanium compounds in textile processing and tanning. Most important of these chemicals was titanium-potassium oxalate, the price of which doubled from 25¢ for imported material prewar, to 53¢ in 1916. The chloride, sulfate, and straight oxalates were also in great demand. From the middle of 1917 to the end of hostilities, the Allies substituted titanium tetrachloride for silicon tetrachloride as a smoke agent, and so pressing was this need that 160 of the 705 tons of rutile and ilmenite produced by the American Rutile Company in 1918 went to the Army and the Navy.[20]

During the war, what was destined to become the most important chemical use of this element developed. In 1916, L. E. Barton assigned his patent [21] covering the preparation of pure titanium dioxide for use as a white paint pigment, to the Titanium Alloy Manufacturing Company. A subsidiary, the Titanium Pigment Company, was formed by William F. Meredith,* and a start made in the manufacture and sale of this material under the trade name "Titanox." The development lagged because of war conditions and conflicting patent claims. In 1921, after a year's investigation and subsequent to a negotiated settlement by which Titanium Pigment took over all the patent rights owned in the United States by the Titan Company of Norway, the National Lead Company exercised its option on half the outstanding stock of the Titanium Pigment Company.[22]

While titanium was becoming more and more a chemical raw material,† other ferroalloys were making sensational strides forward. Armament and ordnance, machine tools and chemical apparatus, all created new and greater demands for special steels. The electric furnace assisted by its ability to produce alloying compounds more quickly and more exactly. As a result, the war period witnessed the early development and commercial introduction of many alloys—whole groups of stainless steels and the heat-resisting alloys—and novel uses of copper, chromium, nickel, zinc, and aluminum, now of great importance in chemical technology. From this time we date the familiar trade names Monel, Inconel, Stellite, Illium, and the various Hastelloys.[23]

Prior to the war, American steelmakers leaned heavily upon Germany for ferrotungsten, and England for ferromanganese. After the

---

* With his late brother, J. D. Meredith, industrial pioneer of the titanium pigment industry. In 1906 he had organized the Titanium Alloy Mfg. Co. and upon the merger with National Lead, he remained active head of the Titanium Pigment Co., later becoming a dir. of the parent corp. Educated at Groton and Princeton, he came of a family prominent in New Jersey since colonial days. He died in Sept. 1943. [See *Paint Ind. Mag. 58,* 357 (1943).]

† The story of the amazing growth of this new industry and the exploitation of the titanium dioxide sands of the Quillon district at the southern tip of India belongs to the postwar period of chemical history.

war, we became an exporter of both alloys. In 1914, a single American company produced ferrosilicon, but by 1917 there were five producers.[24] Of this important three, tungsten had the most sensational war career.

Germans appreciated nicely the strategic position of tungsten and the value of high-speed tungsten steel for tools. The English and we did not. Accordingly, though we were always one of the largest users of tungsten steel and sometimes the largest producer of tungsten ores, world headquarters of trade in the metal and of alloy manufacture centered in Germany. United States production was the world's greatest in 1910 and 1911, when Burma took first place, to be rewon by us in 1916. Thereafter, for the war period, the lead was held by the recently discovered Chinese mines. Customarily, Germany imported tungsten from South America and the East, and her large additional purchases in America during 1913 and 1914 may well have been part of a forehanded plan to accumulate a stockpile in anticipation of war.[25] The war caught us badly unprepared in this metal,[26] with a domestic supply of ore quite inadequate for even normal requirements and but a single producer of ferrotungsten, the Vanadium Alloys Steel Company of Pittsburgh.[27]

The year 1916 was a crucial one in tungsten history. High prices fathered a boom. Mining camps in Colorado and California ballooned into small cities; speculative fever ran high; promoters floated all sorts of dubious companies. With rich ore worth $3 a pound, carefully planned, wholesale thefts became a profitable sideline.[28] Amid this bonanza the Chinese deposits were discovered, and two years later they shipped to this country over 4,000 tons of high-grade ore, more than the total domestic output. The end of war demands and Chinese imports prostrated our tungsten-mining activities. In 1919, Representative Charles B. Timberlake introduced a bill, H.R. 4437, designed to give tariff protection of $10 per unit of WO_3 in crude and concentrated ores, and $1 per pound on tungsten in the metal, powder, alloys, tungstic acid and its salts. The Tariff Commission held hearings in Denver, San Francisco, and New York during the summer of 1918 and on August 21, 1919, the bill passed the House, but it died in committee in the Senate.[29] Conditions went from bad to worse, and during 1920 and 1921, while low-priced Chinese and Bolivian ores continued to be imported, American mines were closed down.[30] The Tariff of 1922 placed duties of 45¢ on tungsten ore and 60¢ plus 25% ad valorem on all alloys. As a result, the price of ore advanced from $3 a unit to $7, and the following year three of the best old American mines, Wolf Tongue, Vasco, and Atolia, reopened.[31]

The war period saw other significant tungsten developments. In

1916, the first American-made tungstic acid had been produced by the Tungsten Mines Company. It has since been a regular if not important item in our domestic markets.[32] In 1913, the famous, fundamental patent for ductile tungsten—U. S. Patent 1,082,933—was granted to Dr. William D. Coolidge.* The application of this invention by the research staff of the General Electric Company, under the direction of Dr. Willis R. Whitney,† led to the tungsten-filament electric-light bulb, the first of a series of discoveries which enormously increased the efficiency and economy of lighting.[33] In 1914, the number of tungsten-filament incandescent lamps made was 100,000,000, representing some three tons of tungsten concentrates. Two years later, the total had doubled and in 1920 it reached 315,000,000.[34]

First of all the steel alloys developed was spiegeleisen, containing some 20 per cent manganese, and at the time of the war, from 15 to 20 pounds of some form of manganese were employed per ton of practically every type of steel manufactured. Standard practice then was to use spiegeleisen in high-carbon steels made by the Bessemer process, and ferromanganese—introduced in 1875 and containing 80 per cent manganese—in open-hearth, low-carbon steels.[35] With the exception of the United States and the Illinois Steel companies, the American steel industry was dependent upon imported ferromanganese, about 90 per cent of which came from England. These two companies produced for their own consumption only, and when on November 8, 1914, Great Britain put an embargo on ferromanganese, our industry faced a critical shortage of an essential material. The British ban was intended primarily to prevent reshipment to Germany, and although it was lifted in March 1915, we continued to suffer serious manganese deficiencies. As late as May 17, 1918, J. A. Farrell, president of the United States Steel Corporation and member of the American Iron & Steel Institute's war committee, told the War Industries Board very bluntly that the entire industry would be forced to close down the following December, unless more manganese ore could be procured from Brazil.[36] The vital needs for manganese and chrome were largely responsible for the setting up of a special Ferroalloys Section, under the

---

* One of the country's most distinguished physical chemists, Coolidge went to General Electric in 1905 as asst. dir. of the Research Labs., from the staff of his Alma Mater, the Mass. Inst. Tech. For his distinguished work on tungsten wire, the dielectric constants of liquids, X-ray tubes, and high-voltage cathode rays, he has won hon. degrees from Lehigh and Union, and medals from half-a-dozen learned societies.

† Whitney, great pioneer of industrial research in America, was called to the new and then ill-defined post of res. dir. of General Electric in 1901 on a part-time basis, and from this frankly experimental beginning, built one of the strongest, most valuable research organizations in the world. By deed and word he has been a potent propagandist for the application of science to industrial problems.

Chemicals Division of the War Industries Board, with Hugh W. Sanford as chief and Chester D. Tripp, his associate.

As was true of most critical war minerals, manganese ore was deeply involved in the shipping problem. Quantities of low-grade material are found in the United States, but in 1914 we produced only 2,600 tons of high-grade ore. Prices skyrocketed, and to encourage domestic producers as much as possible, no effort was made to control them till in the spring of 1918, when the American Iron & Steel Institute made an agreement with ore producers to stabilize the market for a year at $1 per unit,[37] about three times the 1915 quotation. That year American mines produced 310,000 tons of high-grade and 650,000 tons of low-grade manganese ores.

England, mainstay of our prewar ferromanganese supply, had always drawn upon Indian ore. Even with the best intent to aid our steel industry, it was inexpedient, due to the shipping crisis, for her to continue to do so. After we entered the war, such imports were entirely forbidden in order to conserve cargo space from India to England. We turned perforce to the high-grade ore from Brazil and to a less extent from Cuba. The threatening crisis that Farrell pointed out was precipitated in May 1918, when due to a shortage of coal, the railroad bringing Brazilian ore to port was forced to suspend operations. Almost simultaneously the Navy collier *Cyclops*, pressed into service to bring ore from Brazil, was sunk by a submarine en route to this country. In the emergency, 12,000 tons of ore were brought over from England, and several special cargoes of coal sent posthaste to Brazil.[38]

Rapid expansion of open-hearth steel production pyramided the requirements for ferromanganese, and during 1915 several new producers joined the Steel Corporation and the Illinois Steel Company. First, and during the war the most important, was the American Manganese Manufacturing Company, a $12,000,000-consolidation of the interests of the Cuyuna Mille Lacs Iron Company and the Duluth Iron Company, owners of large manganiferous deposits in the Cuyuna Range, Minnesota, and the Dunbar Furnace Company, with a blast furnace at Dunbar, Pennsylvania, and important allied coal and coke interests.[39] The Noble Electric Steel Company, pioneer West Coast electric furnace, brought a 10-ton daily capacity of 80% ferromanganese into production, working up ore from Mendocina County, California;[40] and the Electro Metallurgical Company began making ferromanganese and spiegeleisen at Niagara Falls. At Palmerton, New Jersey, the New Jersey Zinc Company continued to be the country's chief supplier of spiegeleisen, smelted from franklinite, the iron-zinc-manganese oxide, $(Fe, Zn, Mn)''(Fe, Mn)_2'''O_4$. E. J. Lavino & Company of Philadelphia, also started an electric-furnace production of ferromanganese at

Niagara Falls,[41] and Jones & Laughlin, the Maryland Steel Company, and Colorado Fuel & Iron Company all converted some of their furnaces to this purpose to supply their own needs.

During 1917, two additional ferromanganese projects were launched, by the Anaconda Copper Mining Company at Great Falls, Montana,[42] and the Southern Manganese Corporation at Anniston, Alabama, both proposing to work local ores. Neither was in production at the time of the Armistice, and the Southern company, backed by Theodore Swann, was shortly afterwards converted to the production of high-test phosphoric acid. The sudden ending of the war and the consequent slump in the steel industry averted the threatened shortage crisis in manganese. After a sharp, painful readjustment period, during which the American Manganese Manufacturing Company, lately the top producer, closed in a receivership,[43] our manganese industry emerged upon an entirely new basis. Henceforth the chief sources of ore were to be Brazil, Russia, the Gold Coast, and India, not domestic; but the supply of ferromanganese was to come not from British, but from domestic producers.[44]

In 1914, over 80 per cent of the world's supply of vanadium came from a single mine, the Mina Ragra, high in the Peruvian Andes, so inaccessible that the ore had to be packed out on the backs of llamas. That mine was discovered in 1905, and after examination by D. Foster Hewett,* was purchased by a rugged individualist of the old school, Joseph M. Flannery † of Pittsburgh. Almost single-handed he developed this difficult mining property and introduced vanadium into the steel industry.[45]

Flannery's American Vanadium Company built a new plant at Bridgeville, Pennsylvania, just prior to the war, but by 1916 the electric furnace completely revolutionized both vanadium metallurgy and economics. It reduced costs by substituting cheaper coke for aluminum as a reducing agent. It also made practical the use of lower-grade ore, which opened the door for the development of American deposits.[46] The Primos Chemical Company and the Carnotite Reduction Company took advantage of this opportunity. The Primos production, second only to that of the American Vanadium Company, came from roscoelite-bearing sandstone in Colorado. This was reduced on the spot and the hydrous ferric vanadate shipped East for the production of ferrovanadium.[47] Carnotite operations were based upon a projected joint recovery with radium and uranium. However, their ore body was sold

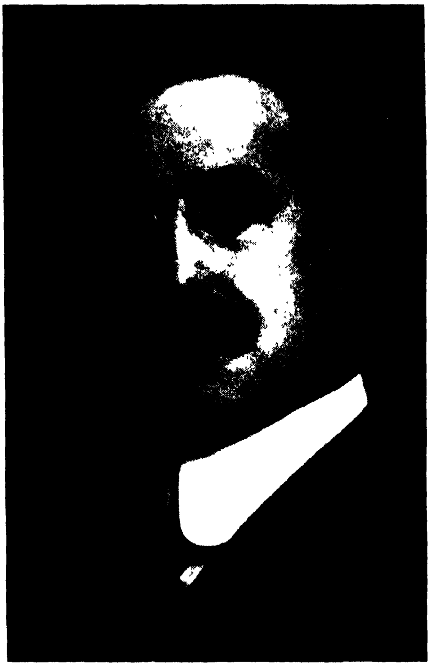
---

* Hewett received his Met. E. from Lehigh (1902) and Ph.D. from Yale (1924). Save for 2 years' teaching at Lehigh and 11 years' practice as a consulting mining engr., his career has been with the Geol. Surv.

† Died in 1920; for account of his work on radium and uranium, see *Iron Age 105*, 641 (1920).

JOSEPH M. FLANNERY

CHESTER D. TRIPP



FREDERICK M. BECKET

J. J. FLANNERY

in 1920 to the Tungsten Products Company of Colorado, which in turn joined with the Radium Company of Colorado, in 1921, under the presidency of Buckley Wells.[48]

In 1919, shortly before the death of Flannery, J. Leonard Replogle and Charles M. Schwab bought out his interests in the American Vanadium Company and organized the Vanadium Corporation of America, capitalized for $30,000,000.[49] The following year they bought the Primos Chemical Company, thus acquiring the largest, most profitable domestic vanadium ore deposits.[50]

During the war ten different firms made ferrovanadium, but by 1922 the Chemical Products Company of Denver, the Radium Company of Colorado, the Radium Luminous Materials Corporation, the Carnotite Reduction Company—all producing ferrovanadium as a by-product of radium—had shut down. In the interval the Goldschmidt Thermit Company became the Metal & Thermit Corporation; Carnotite and Radium of Colorado had merged; American Vanadium became the Vanadium Corporation of America.[51] Only six producers survived: the Vanadium Corporation of America and the Standard Chemical Company, Pittsburgh, both of which owned and worked their own ore deposits; the Electro Metallurgical Company of America, New York and Niagara Falls, and the Metal Alloys, Inc., of Watervliet, New York, which two purchased ore and concentrates; the Metal & Thermit Corporation and the York Metal & Alloys Company, both of New York, which operated on oxides or ferric vanadate recovered in the isolation of radium. Our ferrovanadium requirements were now supplied domestically, though still mainly from Peruvian ore, and we had an exportable surplus which at the time supplied most of the European needs.[52]

Throughout the course of the war, feverish activity stirred in the whole field of ferroalloys, and zirconium furnishes a sample of the activities of those tumultuous times. The deep military secret that the Germans were using a ferroalloy of this metal in light armor plate was ferreted out by French metallurgists and passed on to American collaborators. Tests in France had resulted in enthusiastic reports, and Henry Ford, who had a big contract for tanks, got the idea that here was the ideal protective covering for this new mobile weapon of modern war.[53] He failed, however, to rouse a flicker of interest among ordnance officers of either Army or Navy. Being persistent, however, he went straight to the White House, and the President sent him on to Baruch at the War Industries Board.

Summers and Replogle managed by hook and crook to scrape together a sizable stock of zirconium ore, and on the advice of the National Research Council, turned it over to the Electro Metallurgical

Company. Here it was in the right hands, for the director of research was Dr. Frederick M. Becket,* a metallurgical genius, the one man not only responsible for the outstanding technological accomplishments of this company, but also for the greatest single contribution to American progress in alloys. Making his experiments directly on a large, pilot-plant scale, Becket whipped the technique of ferrozirconium production within two months and was able to ship tons of this hitherto unavailable alloy.[54] Producers of zirconium oxide at the end of the war were the Foote Mineral Company of Philadelphia, which had acquired the Brazilian deposit formerly owned by German interests; Welsbach Company, Gloucester, New Jersey; the Lindsay Light Company, Chicago; and the Pennsylvania Salt Manufacturing Company, Philadelphia.[55]

Less showy than his zirconium adventure, but of substantial benefit to chemical-apparatus makers, were Becket's painstaking studies and gradual perfection of the techniques of the chrome and silicon ferro-alloys. In 1914 both were emerging from the experimental stage, although various chrome steels had been in commercial production many years. They had been developed first in France in 1821 and for their famous hardness were used experimentally in projectiles during the Civil War. Ten years later the Eads Bridge across the Mississippi was built of chrome steel. Although a bright white chromium alloy had been produced in Brooklyn in 1876, the first of the stainless steels, containing 13 per cent chromium, appeared here in 1912 as English imports for use in knife blades.[56]

In searching for a highly refractory metal, it occurred to Becket gradually to reduce the chrome content of 60 per cent ferrochrome, testing the properties of the new alloys at each step. He found what he sought in a series containing 20 to 30 per cent chromium, and shortly afterwards chrome-iron castings were put on the market.[57] Chrome steels were in enormous demand for big guns, and though their superior corrosion-resistant properties were early recognized, shortages due to

---

* Becket, born a Canadian, did his undergraduate work at McGill; his postgraduate, at Columbia. He came to the U. S. in 1895 and became a naturalized citizen. Prior to assuming charge of research for Electro Metallurgical, in 1906, he had been successively with Westinghouse, the Acker Process Co., and Ampere Electrochemical. At the time of his death, in 1942, he was pres. of Union Carbide & Carbon Research Labs. and vice-pres. of both Union Carbide and Electro Metallurgical. He was a real pioneer in the use of the electric furnace, in ferrochrome, ferrovanadium, ferrotungsten, ferromolybdenum, and especially in ferrosilicon and the use of silicon as a reducing agent for producing low-carbon ferroalloys and steels. In recognition of these distinguished accomplishments, he received a D.Sc. from Columbia; LL.D., McGill; the Perkin medal, 1924; Acheson medal, 1937; Elliott Cresson medal, 1940. An original thinker, a bold experimenter, he was a man of great modesty and personal charm. (See *O.P.D. Reptr.* 79, Dec. 7, 1942.)

military needs delayed their wide application in chemical equipment.*

Among the key metals of the war, platinum furnished the most romantic episodes in the grim struggles to make good dangerous deficiencies. It surprised nobody that this "White Queen" should become a nasty problem. It was no secret that nearly 90 per cent of the world's platinum came at that time from Russia and the rest largely from Colombia, these countries producing 250,000 and 15,000 ounces, respectively, in 1913. Our production was very small, and in spite of frantic efforts to increase the output in California, Colorado, and Nevada, and T. W. Gruetter's courageous attempt to wash out the black sands in Oregon in a placer mill,[58] domestic sources never afforded tangible relief. Even before the Bolshevik Revolution, while Russia was still fighting with the Allies, miners drafted for army service reduced the Russian output by three-quarters, and this curtailed supply was all but unavailable.† After the Allies put a strict embargo on all platinum exports in the early autumn of 1915,[59] the metal became a famine item and the price began climbing from $43.86 per troy ounce till, in 1917, it reached $100 and even $108 in the spring of 1918. Then the price was fixed by the War Industries Board at $105.[60]

As the price rose, so did the luxury demand for jewelry and the necessitous demands for magneto points, for chemical platinum vessels, and above all for platinum catalysts in the production of sulfuric and nitric acids and synthetic ammonia.‡ As Grosvenor Clarkson picturesquely phrased it, "the white fingers of women vied with the stinking vats of acid manufacture for its possession." [61] Its scientific zeal fanned by patriotic ardors, the American Chemical Society campaigned against gee-gaws and baubles made of this, now doubly precious metal, and a hapless jeweler whose brazen signs in Detroit streetcars announced—"The Most Extensive Stock of Platinum Engagement Rings All Set with Perfect Diamonds"—drew the withering fire of Charles H. Herty, who had just been named editor of *Industrial & Engineering Chemistry*.[62] The jewelers retaliated, and M. D. Rothschild, chairman of their Vigilance Committee, declared that "selfish chemical interests have been

---

* For a résumé of early technological development of various ferroalloys, see R. M. Keeney's "Manufacture of Ferroalloys in the Electric Furnace" (Bur. Mines, *Bull. No.* 77, 1914) and for the broader picture, H. C. H. Carpenter's review in *Engineering* 13 (May 3, 1935). Writing from the chemical point of view, I deal with the crisis in chrome supplies during the war in connection with bichromates. In like manner, though lead, nickel, and copper are all important metals in chemical equipment, I have considered them primarily as raw materials for their various chemical salts. (W. H.)

† See Appendix XXXVII for an exciting story of one shipment of Russian platinum.

‡ In 1915, J. M. Hill, of the Geol. Surv. estimated that 43,888 oz. of platinum were contained in 1,487,000 lb. of contact mass used in the country's sulfuric acid plants, and that the losses per ton of acid ranged from negligible to 0.25 g. The war period saw an enormous expansion of the contact process. (See *Min. Res. 1915*, I, 150.)

conducting a misleading press campaign against platinum for the purpose of having women who buy jewelry, boycott it in order that they may pull the price down."[63]

The Government, through the War Industries Board, stepped in, and March 18, 1918, the production, refining, and distribution of platinum was placed under the control of a specially created section of its Chemicals Division.* All imports of the metal and its ores were under official supervision and exports were prohibited. Refining was concentrated in the hands of Baker & Company and its affiliates, the American Platinum Works and the Irvington Smelting & Refining Works, despite the protests of Dr. James H. Hill of the Geological Survey, who pointed out that the head of these companies, Charles Engelhard, was German-born and had old, intimate business connections with very prominent German metal interests.[64] Hill's nervous forebodings proved to be quite groundless; indeed both the Geological Survey and the Bureau of Mines were more jittery about platinum than the War Industries Board.[65]

It was not necessary to commandeer the metal from the showcases of the jewelry stores, but a special campaign to round up gifts or sales of platinum to the Government for war use was carried on by the Red Cross and hundreds of women's clubs.[66] The Bureau of Standards lost $10,000 worth of platinum dishes by theft, and similar losses were reported by many colleges and industrial laboratories, so that the American Chemical Society appointed a special committee consisting of R. B. Moore of the Bureau of Mines, chairman; W. F. Hillebrand of the Bureau of Standards; C. H. Kerk of Bishop & Company; and George F. Kunz of Tiffany & Company. The Committee suggested federal registration of platinum vessels with a tax of .01% to pay the expenses, but the war was over by this time and nothing came of it.[67]

Some clever substitutes were able to stretch the limited stocks. In the dental and electrical fields especially, some replacement of the metal was permanent. An alloy of palladium and gold, "Palau," was offered for chemical ware by the Pacific Platinum Works, "Rhotanium" by the Industrial Research Company of Cleveland, and silicon-palladium combinations were successfully used for electrical contact points and spark plugs.[68] "Amaloy," a series of nickel-chromium-tungsten alloys proved suitable for orthodentistry,[69] and P. Roubertie and A. Nemiroski perfected a fluorescent screen of cadmium tungstate for use in radiography.[70]

Behind the scenes platinum became involved in high diplomacy. The

---

* Chairman of the Platinum Section was Charles H. Conner of Kissel, Kinnicut & Co., N. Y., who also served as chairman of the Wood Chemicals and the Gold & Silver Sections, with R. H. Carleton, another banker, and George E. De Nike, a wholesale lumberman, as his assistants.

Colombian Government, disgruntled over the long-delayed settlement of its Panama Canal claims, indicated pretty plainly that it might place reprisal restrictions on the exportation of platinum. Delicate negotiating was needed to overcome this coolness. But the best of these stories is that of the 21,000 ounces brought from Russia, across Siberia, under ambassadorial seal, through Japan, safely to a West Coast port.

In 1917, a small group of American engineers in Russia, headed by Lieutenant Norman C. Stines and some officials of the Russian-English Bank of Petrograd, foreseeing our entry into the war, gradually and secretly accumulated platinum in anticipation of a shortage and high prices in the United States. Armed with special diplomatic couriers' passes, Frederick W. Draper and A. F. Schmidt made the long journey amid perils from robbers, ranging from common bandits to German agents and Russian officials charged with upholding the embargo. They reached this country at the very peak of the market. Though they naturally expected to receive the top price of $105 an ounce, nevertheless, since their precious cargo was consigned to the Secretary of Commerce, it was promptly commandeered. After some bickering, it was purchased by the Government at $90 an ounce, $1,890,000 instead of $2,000,000.[71]

A month before the Armistice, October 1, 1918, platinum was rigidly restricted to war and scientific uses, and a licensing system under Raymond T. Baker, director of the Mint, promulgated.[72] By December 1, however, price control over the metal and any effort to continue the licensing system were both given over. In July 1919, the Government sold 25,000 ounces at $105, almost all of it being snapped up by the jewelry trade which was enjoying its brief but brilliant postwar boom. This sale took quite a little pressure off the market, and although platinum did not decline as precipitously as other metals during the price debacle of 1920-21, the stringency of supply for chemical uses was henceforth relieved.[73] In 1921 the Ordnance Salvage Board proposed to offer for sale 34,150 pounds of surplus contact mass—magnesium sulfate sprayed with platinum chloride—but this was later withdrawn when the Army decided to hold this material as a reserve.[74]

One of the first proposals for the formation of a government-owned and operated corporation, since 1930 so favorite a means of carrying on business enterprises under official auspices, was made in connection with platinum. In September 1919, a bill was introduced into Congress, providing for the incorporation of the "United States Platinum Corporation" with a capital not to exceed $50,000,000 provided from public funds, which corporation should be exempt from all federal taxes. The business of making concessions and leases of the government-owned platinum sands in Alaska was to be entrusted to this agency, paying royalties of one-eighth of its net profits. The bill further provided $100,000 "to be applied to the maintenance of five United States Commissioners of Platinum and Its Allied Products." This measure died in the House Committee on Public Lands,[75] but it laid down a pattern which has since been frequently followed.

In the light of what magnesium meant in waging the Second World War, the supply of the lightest of all structural metals available during the First World War and the uses to which it was put, reveal as in the white glare of a flashlight, one of the most amazing technological triumphs of the astonishing quarter-century between the two conflicts. In 1914 magnesium was a rare metal, produced only in Germany, sold by the pound at $1.65, used almost exclusively in fireworks and photographic flash powders.[76] During the earlier war, similar pyrotechnical uses just about summed up the military demands. Magnesium lighted the flares and star shells that theatrically illuminated No Man's Land between the trenches of the Western Front. A pinch or two added to the bursting charge of shrapnel shells guided the gunners by a puff of white smoke in daylight and a dazzling flash at night. As much as a teaspoonful might be added to aerial bombs for the same purpose, and the early tracer bullets for machine guns and small rapid-fire cannon were steady consumers. In a tentative way a few magnesium-aluminum castings were tried out in primitive airplane frames and engines.[77]

Having the only regular supply of this light and flighty metal so difficult to recover, and when obtained, so hard to handle safely, the Germans had at that time a monopoly of knowledge of its metallurgical and fabricating techniques. They found it useful in lightweight alloys for aircraft construction and they made the first magnesium incendiary bombs, but did not dare to use them.[78]

In the American Army, however, a good case can be made for magnesium sulfate as the most important use of magnesium in 1917-18. Certainly a spanking dose of Epsom salt was the favorite prescription of the old Army doctor. His fixed idea of administering this strong cathartic to every new patient may have lacked discrimination, but it had other merits. Save in rare cases of appendicitis or stomach ulcers it could do no harm. Often it did good. Undoubtedly this bitter draught with its drastic effects served as a wholesome deterrent upon a soldier's ambition to escape duty by reporting at sick call. At all events, magnesium sulfate, having been largely imported from Germany, rose in price from $1.10 per 100 pounds to over $5.00.[79]

But the demand for the metal, though not great, was very real. Within two months after the Germans invaded Belgium, stocks in this country were so low that importers were doling out magnesium to large dealers in photographic supplies in ten-pound lots.[80] Word had come out of Germany that "for the duration" there would be no more exports of this metal. To supply its own requirements, the General Electric Company quickly decided to produce magnesium and it achieved a small, steady output throughout 1915.[81] By the end of the year a number of other firms were also in production.

The electrolytic recovery from magnesium chloride was the approved method and already well known. Sir Humphry Davy had been the first to secure the metal in 1808. He did so by both electrolysis of the chloride and by reduction of the oxide in a current of potassium vapor. Matthiessen laid the foundation for commercial operations by mixing three parts of potassium chloride and four parts of magnesium chloride, adding a little ammonium chloride, fusing and electrolyzing this mixture.[82] Essentially this was the process used in Germany before the war. It was promptly adopted in this country.

The Norton Laboratories was one of the first in the field. At Nashua, New Hampshire, they made magnesium chloride from magnesite from Quebec and California, which was reduced to magnesium at Lockport, New York.[83] The Aviation Materials Corporation was organized in 1915 by George O. Seward and F. von Kügelgen [84] to work the patents they had secured while associated with the Virginia Electrolytic Company.* This company had carried on extensive research in the lightweight alloys of both magnesium and calcium.[85] The Electric Reduction Company also began producing magnesium in the fall of 1915, but the following summer abandoned this project, having more profitable uses for power.[86] Also in 1915, up in Canada the Shawinigan Electro-Metals Company began turning out small quantities of magnesium.[87] So successful were these various enterprises and so modest the demand that, summing up the situation, Dr. William M. Grosvenor wrote [88] that the probable current production is "at the rate of something over a million dollars' worth a year† and will be slightly in excess of the present domestic needs." These needs grew greatly as the munitions requirements rose so that, despite further increases in magnesium supplies, the War Trade Board during 1918 repeatedly refused export licenses even to the Allied Purchasing Commission.[89]

In 1916, the two companies which were to carry forward the American magnesium development during the postwar years, both came into the picture. The Dow Chemical Company naturally enough entered

---

* U. S. Pat. 868,226 (1907), 900,961 (1908), 931,092 (1909), the latter two being assigned to the Virginia Laboratory Co.

† At the market price of $5 a pound this would have been 200,000 pounds, more than twice as much magnesium as the 87,500 pounds produced that year. Though his figures were inflated, Grosvenor was essentially correct in his estimate of the situation, as shown by the shutting down of the General Electric operation in 1917 as soon as any danger of a shortage of this raw material was removed.

through the door of magnesium chloride. This salt was a prominent constituent of the Michigan brine that Herbert H. Dow was already successfully exploiting for its bromine and its sodium and calcium chlorides. The bittern left after these constituents were extracted was largely magnesium chloride, and with importations cut off from Germany, this found a market to the new producers of magnesium[90] and also for conversion to magnesium oxychloride then in demand for the manufacture of special cements.[91] With magnesium chloride in hand, Dr. Dow could not fail to be fascinated by the possibilities of the metal. In July 1916, the first experimental batch of magnesium was produced at Midland, in a 100-pound steel pot, by Professor William Reed Veasey * of Case working as a special consultant under Edwin O. Barstow.† Six months later, at a cost of $225,000, an experimental electrolytic magnesium plant was built, but its cells froze after thirty hours' operation, and it took another six months to tame this balky process, so that Dow's substantial production of magnesium did not get under way till 1918.[92]

The American Magnesium Corporation was organized early in 1917, with a capital of $300,000, by J. J. Devereaux, L. J. Hallenbeck, and E. W. Burdick[93] and began operation at Niagara Falls that year, using a process that involved the electrolysis of magnesium oxide.[94] Under the presidency of I. R. Edwards, it absorbed the Aviation Materials Corporation and during the remainder of the war period continued to operate the two plants at the Falls and at Rumford, Maine. After the war, it took over the operation, also at Rumford, of the Rumford Metal Company, which was the reorganized successor of the Magnesium Manufacturing Corporation that had begun its operation in 1917.[95]

Even before the end of hostilities, two producers—General Electric and Electric Reduction—had dropped out. The Norton Laboratories almost immediately followed their example, so that Dow and American Magnesium were the sole postwar survivors. A maximum production of 284,188 pounds of metallic magnesium had been achieved in 1918.

---

* Veasey, then asst. prof., became head of the Case Dept. of Chem. Eng. in 1928, and in 1936 dir. res. of the Dow Chemical Co. Born in Chase City, Va., Dec. 29, 1883, he was trained at Westminster Coll. and Johns Hopkins (Ph.D., 1907), and honored with a D.E. from Case, 1936. Besides the important part he played in the Dow magnesium development, he did distinguished research in sodium metal and insecticides.

† One of the key men of the original Dow group, Barstow came to Midland immediately after graduating from Case in 1900. At the close of the war, he became production mgr. and was identified with the development of electrolytic cells, methods of oil extraction, process for the manufacture of magnesium, lead arsenate, phenol, benzoic acid, and many other Dow products. He was born at Rockport, Ohio, Nov. 13, 1879, and for years was a leader in civic affairs, serving Midland as pres. of the Community Center and on the City Planning Comm.

EDWIN O. BARSTOW

CHARLES ENGELHARD

Chemical & Metallurgical Engineering

WILLIAM R. VEASEY

JOHN D. RYAN

This plummeted to 48,000 pounds in 1921,* and although the price of the metal had been pulled down from $5 for a pound in 1915 to $1.50, it took a lot of optimism to have faith in the future of this metal and zealous courage to continue its production and spend money for research in its applications and fabrication. Only these two groups persisted. American Magnesium, as a subsidiary of the Aluminum Company, had a keen interest in the metal as an alloying material and potential competitor. Dow, with an abundant supply of raw material and a fixed determination to exploit to the uttermost the chemical possibilities of its brine, had also a logical interest in magnesium. But several times in the ensuing, discouraging years, it was only the abiding faith and dogged perseverance of Herbert Dow, in the face of setbacks and contrary to the advice of many of his associates, that kept this company plugging away at the problems of this metal and gave this country the foundation of the astronomical production needed in World War II.

REFERENCES

1. *Met. Chem. Eng. 10*, 507 (1912).
2. *Ibid. 13*, 501 (1915); J. A. Mathews, *Trans. Am. Electrochem. Soc. 31*, 43 (1917).
3. *Min. Ind. 1917*, 320.
4. *Ibid. 1920*, 371.
5. *Ibid. 1921*, 397.
6. Clark, *History of Manufactures in U. S.*, III, 309.
7. B. Stoughton, *Eng. Min. J. 95*, 98 (1913).
8. *O.P.D. Reptr.* 33 (May 12, 1913).
9. A. S. Cushman, *J. Ind. Eng. Chem.* 7, 934 (1915).
10. *Min. Ind. 1913*, 758; *1914*, 743; E. F. Lake, *Met. Chem. Eng. 11*, 144 (1913).
11. Stoughton, *op. cit.*
12. *Min. Ind. 1913*, 760; *1918*, 711; *Min. Res. 1916*, I, 787.
13. Bur. Mines, *Bull. No. 64* (1913).
14. Am. Iron & Steel Inst., *Bull. No. 2*, 272 (1914); *Min. Ind. 1913*, 757; *1914*, 742.
15. *Min. Ind. 1917*, 694; D. M. Liddell, *Eng. Min. J. 104*, 153 (1917).
16. *Min. Res. 1918*, I, 809; *1919*, I, 719.
17. *Min. Ind. 1917*, 696.
18. *J. Ind. Eng. Chem. 10*, 138 (1918).
19. *Min. Ind. 1913*, 759; *1918*, 711.
20. Prentiss, *Chemicals in War*, p. 240; Spurr and Wormser, *Marketing Metals*, p. 569; G. A. Richter, *Trans. Am. Electrochem. Soc. 35*, 323 (1919).
21. U. S. Pat. 1,205,144 (1916).
22. National Lead Co., *Ann. Rept. 1920.*
23. F. M. Becket, *Chem. Met. Eng. 30*, 391 (1924); F. L. LaQue, *Ind. Eng. Chem.* 32, 1164 (1940); W. H. Barsett, *ibid. 15*, 31 (1923); *Fortune* 49 (July 1941).
24. *Min. Ind. 1917*, 329.
25. W. C. Balke, *J. West. Soc. Eng. 27*, 223 (1922).
26. Hearings Ways & Means Comm. (House 66:1) on H.R. 4437, June 13, 1919, p. 7.
27. *Min. Ind. 1915*, 702.
28. *Min. Res. 1916*, I, 790.
29. *Min. Ind. 1918*, 715; *1919*, 688; *Eng. Min. J. 107*, 1094 (1919); *109*, 211 (1920).
30. *Min. Res. 1921*, I, 217.
31. *Ibid. 1922*, I, 572; *1923*, I, 242; *Min. Ind. 1922*, 698; *1923*, 684; W. Loach, *Min. Cong. J. 20*, 27 (Sept. 1934); C. H. Segerstrom, *ibid. 23*, 50 (1937).
32. *J. Ind. Eng. Chem. 9*, 392 (1917).
33. *Elec. World* 77 (Jan. 10, 1914).
34. *Min. Ind. 1916*, 743; *Elec. World*, Nov. 20, 1920.
35. Baruch, *American Industry in War*,

---

* For production and value of magnesium produced in the U. S., 1915-22, see Appendix XXXVIII.

p. 149; *Machinery 30,* 258 (1923); *Min. Res. 1917,* I, 680.

36. Clarkson, *Industrial America in World War,* p. 376.
37. Baruch, *op. cit.* p. 150.
38. *Ibid.;* Clarkson, *op. cit.* p. 378; *Min. Ind. 1917,* 417; C. M. Weld, Bur. Mines, *War Minerals Invest. Ser. No.* 7 (1918), 12 p.
39. *Min. Ind. 1913,* 493.
40. *Met. Chem. Eng. 13,* 484 (1915).
41. *Ibid.* 482.
42. *O.P.D. Reptr.* 29 (Mar. 25, 1918); *Met. Chem. Eng. 18,* 391 (1918).
43. *Iron Age 110,* 1444 (1922).
44. *Steel 96,* 184 (1935).
45. B. D. Saklatwalla, *Ind. Eng. Chem. 17,* 321 (1925); C. J. Stark, *Iron Trade Rev. 57,* 781 (1915).
46. J. Alexander, *J. Soc. Chem. Ind. 48,* 871, 895 (1929).
47. *Min. Res. 1917,* I, 955; *Min. Ind. 1918,* 742; *1919,* 715.
48. *Min. Res. 1919,* I, 727; *Min. Ind. 1920,* 615.
49. *O.P.D. Reptr.* 71 (Sept. 15, 1919).
50. *Min. Ind. 1919,* 715.
51. See *Min. Ind.* & *Min. Res.* I, 1919-22.
52. *Min. Res. 1923,* I, 249.
53. H. C. Meyer, *Eng. Min. J. 107,* 125 (1919).
54. Clarkson, *op. cit.* p. 383; *Fortune, op. cit.*
55. *Min. Ind. 1921,* 689; *1922,* 695.
56. Clark, *op. cit.* II, 271.
57. C. B. Bellis, *Chem. Met. Eng. 30,* 149 (1924).
58. *Min. Res. 1916,* I, 17; *Min. Sci. Press 3,* 698 (1915).
59. *Weekly Drug Mkts.* 12 (Sept. 15, 1915).
60. Baruch, *op. cit.* p. 164; *O.P.D. Reptr.* 27 (May 20, 1918).
61. Clarkson, *op. cit.* p. 369.
62. *J. Ind. Eng. Chem. 9,* 1004 (1917).
63. *Drug Chem. Mkts.* 9 (June 6, 1917).
64. Engelhard, *Chem. Ind. 39,* 361 (1936).
65. Clarkson, *op. cit.* p. 371.
66. *Drug Chem. Mkts.* 15 (May 15, 1918); *O.P.D. Reptr.* 63 (Apr. 29, 1918), 27 (May 20, 1918).
67. *O.P.D. Reptr.* 108 (Aug. 2, 1920); *Min. Ind. 1920,* 548.
68. *Min. Res. 1916,* I, 17.
69. *Min. Ind. 1916,* 600.
70. *Pharm. Era 53,* 51 (1920).
71. *Drug Chem. Mkts.* 32 (Dec. 19, 1917), 15 (Jan. 30, 1918); *J. Ind. Eng. Chem. 10,* 82 (1918); *Min. Ind. 1917,* 550, *1918,* 571.
72. *Drug Chem. Mkts.* 17 (Sept. 11, 1918); *O.P.D. Reptr.* 29 (Oct. 7, 1918).
73. *Min. Ind. 1919,* 549; *1920,* 546.
74. *Ibid. 1921,* 557.
75. *Ibid. 1919,* 551.
76. *Min. Res. 1915,* I, 739.
77. *Min. Ind. 1918,* 458; *Pharm. Era 51,* 10 (1918).
78. Haynes, *Chemical Front,* p. 85.
79. Bur. For. Dom. Com., *Com. Rept.* 1395 (Sept. 1915).
80. *Weekly Drug Mkts.* 10 (Oct. 28, 1914).
81. *Min. Res. 1915,* I, 737.
82. *Ibid.,* 736; W. M. Corse, *Ind. Eng. Chem. 18,* 894 (1926).
83. *Min. Res. 1915,* I, 737.
84. *Met. Chem. Eng. 13,* 141 (1915).
85. *Min. Ind. 1912,* 577.
86. *Min. Res. 1917,* I, 148.
87. *Ibid. 1915,* I, 737; J. A. Gann, *Chem. Mkts. 30,* 335 (1932).
88. *Trans. Am. Electrochem. Soc. 29,* 521 (1916).
89. C. H. MacDowell, to author, Nov. 16, 1942.
90. *Min. Res. 1915,* I, 737.
91. W. H. Dow, *Ann. Rept. to Stockholders, Dow Chemical Co.,* 1941; reprinted, *Ind. Eng. Chem., News Ed. 19,* 993 (1941).
92. Haynes, *op. cit.* p. 226.
93. *Met. Chem. Eng. 16,* 117 (1917).
94. *Min. Ind. 1917,* 413; *1918,* 457.
95. *Min. Res. 1917,* I, 148; *1918,* I, 14, 21.

Chapter 20

MISCELLANEOUS MINERALS

MERRIMAC MAKES DEAL WITH ALUMINUM COMPANY ON SOUTH AMERICAN BAUXITE—DOMESTIC BORAX IN BRITISH CONTROL FULFILLS WAR NEEDS—U. S. ACHIEVES INDEPENDENCE IN BARYTES—TALC AND SOAPSTONE PRODUCERS PROMOTE WAR-WON MARKETS—OIL REFINING EXPANDS DOMESTIC FULLER'S EARTH INDUSTRY.

REPERCUSSIONS of the First World War stimulated American self-sufficiency in a number of the chemical industry's mineral raw materials. Within so mixed a group of products, gathered together from such divergent sources and applied to so many different uses, naturally many factors influenced these changes. In most instances the compelling cause was the sudden interruption of imports. However, the enforced use of domestic materials or substitutes persisted so frequently after the old channels of trade had been reopened, that these interruptions and substitutions have a larger significance.

Many logical reasons inspire any group of manufacturers with conservatism regarding their raw materials. Instinctively they dislike to tamper with the very foundations of their business. Unfortunately this opposition to change, ably supported as it is by both fear and inertia, often becomes so set that only enormous pressure can break it down. Progress is thus thwarted. The more deeply rooted an industry is in the craftsman's rule-of-thumb methods, the more difficult the introduction of new materials or new processes—the two are frequently closely related. The struggles to introduce chlorine as a bleaching agent and to substitute soda alkalies for pot-ashes, identified with the very birth of the chemical industry, were greatly assisted by the Industrial Revolution. From the very beginning, salesmen of chemicals have had to fight this battle against stubborn resistance to change on the part of their customers. Of necessity, they have been missionaries of new ideas. Fortunately every innovation launched has helped to break up old habits of inertia, and in this sense the First World War came at an opportune moment.

Though the very nature of chemical manufacturing, involving chemical change and frequently presenting a choice of distinct raw materials and alternate processes, encourages flexibility, nevertheless, the chemical industry in this country prior to 1914 was not wholly free from this stiff-necked brand of backwardness. World War I opened up many chemical opportunities by excluding foreign competitors from domestic markets. It also compelled our chemical makers radically to revise many of their own operations. The wartime development of the coal-tar chemical industry is the shining example of the first instance. The switch from pyrites to sulfur in the manufacture of sulfuric acid is no doubt the outstanding example of internal change, but a number of similar developments were accomplished among less well-known materials.

All these forced innovations,[1] both within and without the chemical industry, limbered up the thinking of many chemical executives and plant operators. It was fine preparation for the more ready acceptance of the highly revolutionary innovation that followed the war, the first large-scale, industrial use of man-made chemical materials, notably the synthetic fibers, the early plastics, and the cellulose lacquers. The stigma of connoting a cheap and nasty substitute clung to the adjective "synthetic" for years, but the forced substitutions of World War I encouraged many manufacturers to try out these new chemical materials.

Shortly after the outbreak of the war, in one of the first articles dealing with the chemical opportunities of the South, Arthur D. Little summarized the nation's chemical resources, pointing out that the United States was producing 57 varieties of useful minerals.[2] Among the non-metallic group, although we had supplies sufficient to provide an exportable surplus, for various good reasons we continued to import a number of these. In this category fell pyrites, bauxite, barite, tripoli (diatomite, kieselguhr), chalk, talc, fuller's earth, pumice. Our dependence upon imports was very real in the case of mica, graphite, asbestos, kaolin and ball clay, umber and sienna, Naxos emery,[3] and Dr. Little might have added cryolite.

Much of this buying abroad was based upon the belief that only foreign types of many minerals provided the quality necessary for specific needs. Sometimes this belief was well grounded. In a number of cases it represented a prejudice in favor of "imported" goods that was born in colonial days. Shipping stringencies made it necessary for us to use domestic materials or to find supplies in Canada or South America. A number of chemical processes had to be revised and several cherished beliefs were disproved.

Based on definite analysis, chemical manufacturers favored the so-called red bauxite for the production of alumina hydrate because of its low-silica content. White bauxite, low in iron, was their choice for sulfate of alumina. Both grades were being imported from France, though the imported white bauxite was in direct competition with the domestic material, chiefly from Arkansas, which is generally even lower in iron.[4] In the war period French imports were practically cut off and at the same time a tremendous expansion took place not only of aluminum metal and aluminum refractories, but also of various aluminum chemicals, especially filter alum (aluminum sulfate) in water purification.[5] These years saw, too, the initial development of the bauxite deposits in British Guiana and the neighboring Dutch colony of Surinam. After the war these mines usurped from France first place as suppliers of bauxite for chemical manufacture.[6]

An American chemical company played an interesting, constructive part in the initial development of these South American deposits.* Back in 1912, when Dr. Paul Héroult, the Frenchman who independently of Charles Hall discovered the electrolytic process of reducing aluminum, was at Whitney, North Carolina, building a plant for the Southern Aluminum Company, subsidiary of the Aluminium Française. There he was visited by his old friend Henry Howard of the Merrimac Chemical Company, which was a large maker of hydrate of alumina by the Bayer process.† Howard, who was familiar with American bauxite supplies, spent a couple of weeks with Dr. Héroult's right-hand man, Donald F. Campbell of London, prospecting the southeastern mines to locate a near-by supply for the electrolytic plant. Campbell told him of rumors current in London that an exceedingly rich deposit of bauxite had been found in British Guiana and that it had already been acquired by the Aluminum Company of America. Campbell had not seen an analysis, but the story was that this ore was exceptionally high in alumina and very low in both iron and silica. Howard was interested and disturbed, and two years later, in the spring of 1914, when he was in Paris to discuss a renewal of Merrimac's contracts with M. Plagniol, president of the French Union de Bauxite, he inquired what was known in France about the British Guiana deposits.

"They are wonderful," exclaimed Plagniol, "and they were first offered to us, but my directors would not permit me to acquire control. Now the Aluminum Company has them all sewed up. Would you like to see samples and our analyses?"

Howard examined both with keen interest. Judged by American standards the appearance of the Guiana bauxite was misleading, for

---

* For details I am indebted to Henry Howard, who placed at my disposal the unpublished MS "Notes" on his business career. (W. H.)

† "This Merrimac plant was the first Bayer process plant in the world after the original operation at Elabuga on the Kama River, Russia, where in 1913 I engaged Dr. Bayer to come to Woburn to design and start Merrimac's installation. In 1895 Dr. Héroult studied this plant before building his own, much larger one at Gardanne in the south of France. In return for this privilege, the works of the Aluminium Française were always open to me." (Henry Howard, to author, Aug. 23, 1943.)

while analysis * revealed a material exceptionally low in both iron and silica, it looked exactly like an American ore that was obviously high in silica. He tucked these facts away in his retentive memory and went off to Spain to confer with Merrimac's pyrites suppliers.

Several weeks later in London, through Donald Campbell, Howard met J. W. Cobb, holder of the original concession of the Crown Lands which the Aluminum Company had an option to buy at any time for $75,000. This option was kept in force by paying Cobb a monthly fee of $250. Cobb promised to let Howard know immediately if the Aluminum Company should allow the option to lapse, and Howard went off to spend the week end with Clinton Chance of the Chance-Hunt Chemical Works. On his return late Sunday evening he found a message to telephone Cobb.

"The Aluminum Company have cabled canceling their option. Are you interested?"

"Very much. Come right over and bring all the papers with you."

That same night Howard secured a new option on the Guiana concession and the next afternoon he was in Paris offering Adrian Badin of the Aluminium Française a 90 per cent interest in the deposits to be developed pro rata with Merrimac on this same division of all costs. This proposal was promptly accepted, and within the month an expert French analyst who spoke English, equipped with a portable analytical laboratory, met B. P. Curtis of Merrimac at Georgetown, British Guiana, to survey and appraise the property. The analyses checked with the samples sent to France and the Curtis report was enthusiastic.

To keep the record clear, Badin had cabled to Arthur V. Davis, president of the Aluminum Company, that since it had given up the Cobb options, Aluminium Française and Merrimac were stepping into its place. Davis replied at once that the Aluminum Company had no objection to offer, but they later had a great change of heart. Not only did they do all in their power to hamper Curtis' investigation, but when he began gathering up options on adjacent bauxite property, not on Crown Land, Aluminum's representative immediately followed suit, with the result that prices began to rise rapidly. Advised of these developments by cable, Henry Howard called Arthur Davis on the telephone and pointed out that whatever might be the outcome of the fight

---

* Representative of the various types of bauxite, W. S. Landis gives the following analyses:

		France	*Arkansas*	*South America*
Al_2O_3	%	75.0	57-60	58-61
SiO_2	%	1.0	4-7	2-4
Fe_2O_3	%	12.0	2-7	2-4
H_2O	%	12.0	28-30	28-31

(From *Rogers' Industrial Chemistry*, 6th ed., I, p. 949.)

over rights to the Crown Land, it was pure folly for the two companies to bid against each other in buying up new property. He suggested they work in harmony and go halves on the result. Davis assented and invited Howard to come down to his summer place at Jamestown, Rhode Island, to arrange details.

A second dramatic coincidence now thrust itself into this business deal. The war had broken out, and the day before the Jamestown conference Badin cabled that he must withdraw from the Guiana bauxite matter. The French Government had forbidden the exportation of any capital for whatever purpose. Obviously this changed and complicated Merrimac's position, but Howard decided the proposition was so favorable that he would go ahead. He therefore took to Jamestown with him able legal counsel, Archibald R. Graustein, then of the Boston law firm of Ropes, Gray, Boyden & Perkins, later president of the International Paper Company. Reviewing the situation on the way down, they concluded the only fair thing was to tell Davis frankly of the great change that had developed in the past forty-eight hours.

During the early part of the conference Davis seemed receptive to the idea of working together, especially on new purchases. However, when he learned that the Aluminium Française was now obliged to abandon not only this bauxite development but the Southern Aluminum Company in North Carolina, too, he stated quite bluntly that this completely changed the situation and that he did not care to commit himself any further at that time.

Jamestown is on an arm of Narragansett Bay, a twenty-minute ferry trip from Newport, and on the way back Howard said that it was his guess that Davis would have his lunch at 1 o'clock, take the 2-P.M. ferry, and cable to Badin an offer for his 90 per cent interest in the bauxite concessions.

"It seems to me," he added, "there is but one chance to save our position. We can get to the cable office by 12:30. A rush cable to Badin should be delivered to him by 5:30 Paris time. He generally stays at his office till 6 o'clock. If he gets it before he leaves and he acts immediately we will be saved because he will not receive Mr. Davis' cable till the next morning."

A carefully worded message was sent regretting that Badin could not go on and asking him immediately to mail papers to Campbell in London, releasing his interest and turning it over to Merrimac. The cable did arrive in time and Badin acted at once. The following day, before this letter reached Campbell, he tried to recall it; but it was then too late. Campbell had already made the transfer as authorized and the Merrimac Chemical Company became the legal owner of the entire rights to the concessions, at least in so far as Cobb was able to give them.

Then followed what Henry Howard characterized as "a merry fight, the most interesting I have ever taken part in." Development of a tropical mining concession was admittedly too big a proposition for Merrimac to handle alone, and after unsnarling some knotty legal complications and coming to terms, it was finally agreed to transfer the concessions to the Aluminum Company's bauxite subsidiary for a cost to it, including all legal expenses, of not more than $50,000. This was actually less than the original Cobb option price. The Aluminum Company contracted to supply Merrimac with all its requirements for British Guiana bauxite for 40 years at an exceedingly low price. Before Curtis returned, he had followed up the rumor of bauxite discoveries in Dutch Guiana by visiting that country and signing up options on several valuable properties. These concessions were also traded to the Aluminum Company for a clause in the contract that gave Merrimac the right to call for Dutch Guiana bauxite if for any cause the mining operations in British Guiana were suspended or transferred to the other point. Under the circumstances, these terms were generous, and as Howard notes in his unpublished memoirs, "We could, of course, have held them up for much more, but in view of the fact that we expected to work with them for years to come, it seemed to us much wiser to be liberal in the settlement and to establish friendly relations from the outset."

The first bauxite shipments from British Guiana came through in 1917. War demands and shutting off of imports from France made it expedient to rush this property into production. The first bauxite from Surinam, Dutch Guiana, reached this country in 1922. Since then it has been quite consistently our largest supplier.

Repercussions of the European conflict upon borax were quite different.[7] Direct effects upon the American industry, felt chiefly through rising prices and increased exports to Canada and England, were comparatively slight. In boron compounds we were quite self-contained, and so great was our domestic consumption that, though the United States was the world's largest producer,* Chile, our nearest rival, supplied some 75 per cent of the rest of the world's demands.[8] At this period California was the sole borax-producing state, and the principal ore mined there was colemanite, a natural calcium borate which was converted to borax (sodium borate) by treatment with sodium carbonate. After the war, borax recovered as a by-product in the Searles Lake potash enterprises, appeared on the market and during the 1920's was a factor in reducing the price of borax and boric acid so

---

* For U. S. production of borate ore and borax, see Appendix XXXIX.

that new uses were opened up.[9] These, however, were distinctly postwar developments.

In 1913, control of the largest American producing company passed wholly to Borax Consolidated, Ltd., the British syndicate that also controlled the Chilean output. Back in 1899, the colorful pioneer of the American industry, F. M. Smith, universally known as "Borax Smith," had merged his Pacific Coast Borax Company with this international group which was being gathered together by Richard C. Baker, a British financier. Smith remained as president and active head of the American company, and indeed the consolidation must have been tenuous, for in 1913, when Smith's bold ventures in California real estate and street railway companies went askew and he was forced to sell his holdings, he was reported to have disposed of 95 per cent of Pacific Coast common shares for about $3,000,000.[10]

Eight years later Smith was again back in the borax business. His West End Chemical Company, organized originally to extract borax from the Searles Lake brines, purchased an important deposit of colemanite in Clark County, Nevada. Smith's shrewdness in borax was once more demonstrated, for he paid only $250,000 for this deposit. It was the first important find of this mineral outside of California and contained more than half a million tons of borate ore. In July 1922, his Anniversary Mine opened up, but a few years later, in 1926, having again slipped into financial difficulties, he was forced to sell his interests and resign as president of West End.[11]

Once in full control of the Pacific Coast Borax Company, the British owners replaced the picturesque 20-mule teams which hauled their ore from Death Valley to the railway, with a spur line connecting their Biddy McCarthy and Monte Blanco mines with the Tonopah & Tidewater Railroad at Death Valley Junction. A narrow gauge track was laid at a cost of $400,000 in 1914, and a large calcining plant was built at the Junction to boost the lower grades of ore before shipping to the refineries.[12] At the same time, they purchased for $4,000 a recently discovered deposit of colemanite in the Kramer district of San Bernardino County, California. This lay 369 feet beneath shale, but was reported to be high-grade material in a layer some 410 feet thick.[13] About this time, the Stauffer Chemical Company, important San Francisco refiner of borax, bought the Russell Borax Mining Company's property in the Ventura district, and in 1917 took up another newfound deposit at Cuddy, Kern County, California. This was developed by a Dr. Suckow of Los Angeles and a United States Borax Company which never got into production. After the war, the interests which had sold out the Russell property to Stauffer organized the Death Valley Borax Company.[14]

During the war the price of borax and boric acid almost doubled—from 4-4½¢ a pound to 8¢, and from 7-8¢ to 12¢, respectively[15]—but the curtailment of export and falling off of domestic demand in 1920 soon brought prices down half-way to the prewar levels.* At this time the chief producers of borate minerals were the Pacific Coast Borax Company, which occupied a dominating position; the recently organized American Borax Company, operating a mine and new calcining plant in Nevada; the West End and Stauffer Companies, and the American Trona Corporation, producing from the Searles Lake brines. The refiners and makers of boric acid were Stauffer in San Francisco, confined to West Coast and Japanese trade; Thorkildsen-Mather Company, Chicago; and Charles Pfizer & Company in New York.[16] There had never been any tariff on crude borates, but the Underwood Tariff provided for ¾¢ a pound on boric acid and ⅛¢ on refined borax. These rates were raised by the Fordney-McCumber schedules to 1½¢ for the acid and ½¢ for borax.[17]

While paving the way for the supremacy of American borax in world trade,† the war encouraged greatly another important mineral industry, barytes, and gave the country a new barium chemical industry based upon it. Although barytes or barite—natural barium sulfate—had been mined in this country since the close of the Civil War, nevertheless, a third to a half of our consumption of this mineral had been supplied by Germany which, thanks to an exceptionally high-grade material (96% $BaSO_4$ against 92% for American), pretty thoroughly dominated world markets. The only barium product manufactured in the United States was the white pigment and filler, lithopone, consisting of barium sulfate, zinc sulfide, and zinc oxide, used in the paint, rubber, and oilcloth industries. The German imports of 36,456 short tons in 1914 dwindled to virtually nothing during the war years and never again became considerable. During the same years the manufacture was initiated in this country of the following barium compounds: the chloride, carbonate, peroxide, hydroxide, and nitrate, and we achieved lasting chemical independence in this group.[18]

Back in 1866, one Turner first undertook the mining of barytes at Henley on the Osage River in Cole County, Missouri. He sold a roughly washed product in St. Louis for $120 a short ton. During the next fifteen years other mines opened in Missouri and Virginia, and the price having been gradually lowered to $60 a ton, this pioneer miner

---

* Postwar prices of these compounds are in Appendix II.

† This came later, during the late 1920's, and was partly due to the growing borax output as a by-product of the Searles Lake potash operations, but chiefly to the discovery of a new, economical source in the mineral rasorite or kernite—hydrated sodium borate.

sold out. His mine was reopened by the Bryant Barytes-Lead Mining Company in 1911, when the increased uses of lithopone and blanc fixe (precipitated barium sulfate) in the pigment field stirred up considerable interest. This company installed a new plant, the first steam mill in the country for the concentration of barytes, and that same year the Wristberg Mining & Milling Company also built a new mill.[19] Mechanical improvements in the decrepitation process at the Tahomu mine encouraged other miners of barite-blende ores to step up the output of barytes.[20] This same year the United Zinc & Barytes Company was incorporated by H. E. Latter, W. J. Maloney, and O. J. Reichard for $1,000,000.[21]

These Missouri barytes, marketed chiefly in the ground form, were sold at St. Louis. Thanks to the freight rate advantages, they supplied the interior and Western states, while New York, where prices were set by imported material, sold the Eastern seaboard consumers. Prewar price differentials were imported crude, $5.50 to $6 a ton; ground, $18.50 to $24 (tariff $1.50), c.i.f. New York; domestic, $4.50 to $5.15; ground, $8 to $13, f.o.b. St. Louis.[22] At St. Louis the principal operators were Nulsen, Klein & Krausse Manufacturing Company, the J. C. Finck Mineral Milling Company, and George S. Mepham & Company.[23]

When German imports stopped * barytes production was naturally stimulated, not only in the Missouri fields, but also in Georgia, Tennessee, and Kentucky. Later this expansion extended to Colorado and Nevada, where the American Barium Company was formed in 1915 by A. D. Ayres, W. M. Gardiner, G. F. Cosby, C. W. Osborn, and L. Wortman.[24] Some importations were even made during the war from Alaska.[25] One of the pioneers of the industry was brought back into the business, for M. H. Dingee, who from 1888 to 1903 was the head of the Dingee-Weiman Company which sold out to the Nulsen, Klein & Krausse interests, became active in the recently organized Central Pigment Company of Nicholasville, Kentucky.[26] His old partner's son, J. E. Weinman of Pittsburgh, also reentered the barytes business with mines in Virginia and Kentucky.[27] An old mine near Bristol, Tennessee, closed in 1909, was reopened by the Virginia Zinc & Chemical Company.[28]

Pigment makers also stepped into the barytes field to protect their raw material supply. The Krebs Pigment & Chemical Company of Newport, Delaware, purchased 40 acres of mineral land near Cartersville, Georgia. Production was begun here during the summer of 1915,

---

* German prewar exports to the U. S. represented in part refined barytes and barium chemicals worked up from crudes imported from England, but the crudes never came to this country. During the war Germany, cut off from Spanish pyrites and Sicilian sulfur, produced sulfuric acid from her own barytes.

from which they planned to secure some 15,000 tons of crude barite a year.[29] More interesting from the chemical point of view, was the move of Henry and Maximilian Toch.* They organized the Durex Chemical Corporation and took over the W. D. Gilman plant, started in 1903 at Sweetwater, Tennessee, where the first barium carbonate in America had been produced. Toch Brothers enlarged and modernized this operation and made it into one of the most important of barium developments of the war period.[30] The Commercial Chemical Company of Chicago was also an important producer of carbonate at this time, and there were probably 15 other companies, war babies which did not live, which made various barium chemicals during 1915-18.

Shortly before the outbreak of the war, Hugh and J. C. Rollin, partners in the Hedworth Barium Company, Ltd., of England, original and largest manufacturers of barium peroxide, organized the Rollin Chemical Company. With E. C. Young in charge, they built a plant at Charleston, West Virginia, designed to produce 3,000 tons a year of this double oxide which at the time was used as an oxygen carrier in the preparation of hydrogen peroxide.[31] This was then an important use, since replaced by the electrolytic process. The output was of strategic value since the failure of supplies from Germany forced the Hydrox Chemical Company, large makers of hydrogen peroxide for the drug trade, to suspend in 1915.[32] From this same peroxide process, precipitated barium sulfate (blanc fixe) had been prepared, but the Rollin people began direct manufacture in this country in 1915. After the war, revisions in this process markedly improved the quality of this product. Though eventually replaced by lighter and cheaper white fillers, blanc fixe remained an important item with the Rollin Company, succeeded in 1923 by the Barium Reduction Corporation, of which James J. Riley was president.

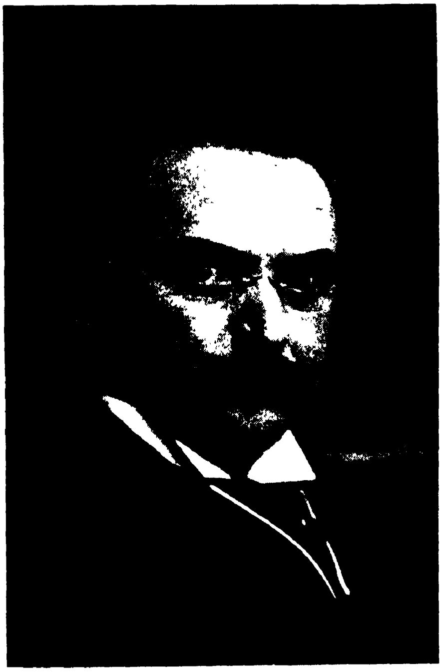
Specially refined barium sulfate is used in X-ray photography and during the war this type was put on the market by the Mallinckrodt Chemical Works, as a companion product to their bismuth subcarbonate, also used for this purpose.[33] Barium chloride was also produced in this country during the war, a leading manufacturer being the Solvay

---

* The Toch brothers, who succeeded to the paint and pigment business established by their father, Moses, in 1848, were prominent figures in this field. Henry, the businessman, was for nearly 50 years head of Toch Bros., Inc. He was public-spirited, a leader in many paint trade organizations, and a generous philanthropist, besides being an amateur artist of merit. He was hon. pres. of the Y.M.H.A. and a member of the Century and Harmonic Clubs. He died July 2, 1933. Maximilian, the chemist, was trained at N.Y.U. and Columbia and taught industrial paint chemistry at C.C.N.Y., Cooper Union, and N.Y. Acad. Design. He was in charge of camouflage for the Army, 1917-19, and made distinguished contributions to the chemistry of paints and permanent colors. He was pres. of the Chemists' Club and Am. Inst. of Chemists, and vice-pres., Soc. Chem. Ind.

PAUL L. HÉROULT

HENRY J. KREBS



MAXIMILIAN TOCH

HENRY M. TOCH

Process Company, which acquired its own barytes mines in the Eastern area and later produced other barium salts.[34] Other companies that helped this country achieve barium chemical independence were the Grasselli Chemical Company, the General Chemical Company, and the Cherokee Chemical Company.*

Among the minerals used as pigments and fillers—various clays, talcs, etc.—a notable effect of the war was the discovery on the part of American industrial consumers that in many instances we had within our boundaries materials equal in all respects to certain choice or special grades previously bought abroad. Necessity thus became a patriotic virtue. More importantly, American producers were encouraged to more careful grading and more scrupulous methods of refining.

Although the United States produced and consumed more talc and soapstone than all the rest of the world, and in 1913 the domestic output surpassed all former records, production of these minerals was greatly increased during the war. This was largely because of the substitution of ground talc for English chalk in the paper industry and for graphite in foundry facings.[35] A "munitions demand" was ground-talc foot powder for the Army, and at this time the demand from the tire industry began to be of some consequence. New York was the outstanding producer of talc at the beginning of the war, but at the end Vermont had taken this position.† Virginia was, and still continues to be, the leading soapstone-producing section of the world, shipping in 1918 more than 15,000 tons, much of it in cut slabs used for chemical laboratory tabletops. North Carolina, while not a large producer, came to the fore at this time as the leading producer of high-grade talc for the toilet-goods trade, supplanting the so-called French talc formerly imported chiefly from Italy.[36]

Talcum powder was one item of the toilet-goods industry picked out for special emphasis in a sales campaign waged by American manufacturers. The timely opportunity presented by war enthusiasms was capitalized in an attempt—not a very successful attempt, it must be admitted—to dispel the charm the foreign label held for American women.[37]

The ascendancy of Vermont as a talc-producing state was due not a little to the expansion of the Eastern Talc Company, which had started near Roxbury in 1906. By 1911 it operated four mines (Baintree, Bethel, Stockbridge, and Rochester) and by 1914 produced 6,000 tons monthly or more than the total output of France and twice that of Italy. Its Rochester mill was said to be the largest in the world and the Company held reserves estimated at 2,800,000 tons of talc rock.[38]

---

* For barytes statistics, 1912-22, see Appendix XL.

† Talc and soapstone statistics are in Appendix XLI.

In 1923 this company merged with the Magnesia Talc Company and the Johnson mills of the American Mineral Company, and the consolidation—Eastern Magnesia Talc Company—was incorporated in Vermont with a capitalization of $1,500,000.[39] This was the first time this industry had any operation of such size and strength, having been predominantly a field of many comparatively small independents.*

After the end of the war, Eastern Talc's president, Freeland Jewett, became the prime mover and first president of the Talc & Soapstone Producers' Association; its secretary was R. B. Ladoo, mineral technologist of the Bureau of Mines. The Association adopted a vigorous program that featured two hitherto undreamed-of cooperative activities: campaigns of industrial advertising for talc and for a protective tariff.[40] This industrial promotion campaign was one of the first of its kind, and considering the type of raw material marketed, was an exceptionally forward-looking, constructive effort to hold the new markets won during the war. As a result of the concerted tariff action the Fordney-McCumber Bill provided duties of 25% ad valorem on ground talc and soapstone and 1¢ a pound on cut or sawed crayons, disks, etc. Manufactures of these minerals (except toilet preparations) became dutiable at 35% ad valorem undecorated, and 45% decorated.[41]

Fuller's earth (a colloidal hydrous silicate of alumina widely found in nature) occupied a position quite similar to talc. Originally used for cleansing and thickening woolen cloth, an old operation known as fulling, the supply for our textile industries was traditionally imported from England. Prior to the war, however, its use for clarifying petroleum and vegetable oils had been found. Consumption grew rapidly to an average, for the decade preceding 1914, of 16,851 tons of imported and 50,759 tons of domestic, respectively 56 and 168 times greater than the averages of 1867-76.[42] During the same time the price of imported material declined from $10.54 to $7.68. Most of this growing consumption of domestic fuller's earth was in the petroleum industry. Florida was the chief producing state and most of its fuller's earth went to petroleum refiners, but Arkansas and Texas both loomed large in domestic output. At this time California and Georgia were less important than they have since become.†

The superiority of domestic material for petroleum refining was generally admitted, and just prior to the war, the Bureau of Mines investigated its suitability for vegetable and animal oils. Dr. Charles L. Parsons found a few cottonseed oil mills using domestic fuller's earth, "whereas others have been unable to substitute it successfully for Eng-

---

* Appendix XLII lists the talc producers in 1922.

† See Appendix XLIII for fuller's earth statistics and XLIV for principal producers in 1922.

lish earth in their practice."[43] Tests revealed that grades of fuller's earth were available in this country as good as the English or even better for refining fatty oils. All that was required was that American producers "exercise a careful and intelligent control of the preparation of their output and its application to the bleaching of oils." Throughout the war this difference of opinion was maintained within the edible oil industry, so that the Shipping Board, for whom C. K. Leith studied the question, did not recommend to the War Trade Board that an embargo be enacted, though the regulations issued April 22, 1918, did rather rigidly restrict import licenses.[44]

Without sufficient direct bearing upon our chemical developments to justify detailed consideration, the story of the various clays, used principally in ceramics and refractories—kieselguhr and diatomaceous earth—and a number of allied miscellaneous minerals, generally had a story during the World War I period quite similar to barytes and fuller's earth. Domestic production was increased to replace curtailed imports; grading and refining techniques improved; and frequently the new markets won were held more or less permanently.

These miscellaneous minerals were handled in the War Industries Board, and most ably handled by Charles Catlett, a consulting chemist and geologist of Staunton, Virginia, assisted by H. F. Staley, a technologist of the Bureau of Standards. Operating as the Refractories Section of the Chemicals Division, these men promoted domestic sources of supply by careful study of the grades and types available in this country; by encouraging production; by initiating scientific research in industrial applications. At their instance, for example, the Refractories Manufacturers' Association and the Bureau of Standards maintained a fellowship at the Mellon Institute to set up specifications based upon performance and to simplify the sizes and shapes of refractory bricks. Though the Armistice came before final action was taken, these efforts were later to bear fruit.[45]

More pertinent to chemical interest because of their forecast of legislative trends, were several mineral laws enacted in wartime. The first and most significant of these was the War Minerals Bill introduced by Senator Henderson, August 27, 1918; passed the Senate September 11, the House September 27; signed by the President, October 5.[46] It thus became law too late—the Armistice came five weeks later—to have any practical results, but its provisions were exceedingly prophetic.

The original bill put at the disposal of the President the then-big sum of $50,000,000, a revolving fund for the purchase of certain ores, minerals, etc., to be used, allocated, or sold as he directed, in the interests of national security. Contracts for future production might be executed and prices set. The proposed law therefore gave the Executive effective working control over the mineral industries. It also embodied the new concept of a government-owned corporation to function with all the powers and rights of private, incorporated companies in order to carry out the bill's provisions. The House did not relish these blanket powers to the President and it effectively crimped them by striking out the price-fixing authority and reducing the over-all appropriation to $10,000,000.[47] On the plea of war necessity the available funds were restored in conference, but the price-fixing powers were not granted.

Adjustment of war contract and damage claims in the minerals field proved so specialized and troublesome that Congress set up a War Minerals Relief Commission. Former Senator J. F. Shafroth of Colorado was named the head, with Philip M. Moore of St. Louis and ex-Representative M. D. Foster of Illinois, members. The sum of $8,500,000 was earmarked to meet these 1,287 claims. Hearings were held during the spring and summer of 1919, and final payment of all claims was completed October 27, 1923.[48]

REFERENCES

1. W. Haynes, *Chem. Mkts.* 148 (1931).
2. *J. Ind. Eng. Chem.* 7, 373 (1915).
3. *Min. Res. 1917*, I, 11a.
4. *Min. Ind. 1913*, 51.
5. C. P. Hoover, *Eng. News* 77, 4 (1917); G. T. Prince, *ibid.* 54.
6. For bauxite supplies and uses, see L. Litchfield, *Chem. Ind. 48*, 154, 290 (1941); F. C. Frary, *Trans. Am. Inst. Chem. Engrs. 31*, 3 (1934-35); Edwards, Frary, and Jeffries, *Aluminum Industry*, I, pp. 71, 108.
7. Sources of data, C. E. Dolbear, *Met. Chem. Eng. 13*, 564 (1915); H. L. Harris, *J. Am. Pharm. Assoc.* 7, 858 (1918); W. F. Dingley, *J. Chem. Educ. 8*, 2112 (1931); *Fortune* 40 (Nov. 1932); R. M. Curts, *Chem. Ind. 47*, 366 (1940).
8. *Min. Ind. 1914*, 78.
9. See Chap. 15; *Min. Res. 1919*, II, 74.
10. *O.P.D. Reptr.* 48 (Oct. 27, 1913).
11. *Min. Ind. 1921*, 73; *Pharm. Era 54*, 266 (1921); H. S. Gale, *Eng. Min. J. 112*, 524 (1921).
12. *Min. Ind. 1914*, 76.
13. *Ibid. 1915*, 65.
14. *Ibid. 1914*, 76; *1915*, 64; *1917*, 70; *Min. Res. 1920*, II, 130.
15. Tariff Comm., *Tariff Inform. Surv. No. A-1*, 11 (1921).
16. *Min. Ind. 1922*, 80.
17. *Ibid.* 83.
18. I. F. Stone, *J. Ind. Eng. Chem.* 7, 990 (1915); Tariff Comm., *Tariff Inform. Surv. No. A-4*, 9, 17 (1921).
19. F. C. Bryant, *Eng. Min. J. 95*, 317 (1913); *Min. Ind. 1913*, 43.
20. *Min. Ind. 1913*, 43.
21. *O.P.D. Reptr.* 19 (July 28, 1913).
22. *Min. Ind. 1913*, 45.
23. *Ibid. 1914*, 65.
24. *O.P.D. Reptr.* 32J (Nov. 15, 1915).
25. *Min. Ind. 1915*, 55.
26. *O.P.D. Reptr.* 15 (June 4, 1917); *Drug Chem. Mkts.* 17 (Oct. 31, 1917).
27. J. J. Riley, *Chem. Ind. 39*, 14 (1936); *Min. Ind. 1914*, 67.
28. *Met. Chem. Eng. 14*, 399 (1916).
29. *Min. Ind. 1914*, 66.
30. Riley, *op. cit.* p. 16; *J. Ind. Eng. Chem. 9*, 337 (1917).
31. *O.P.D. Reptr.* 35 (June 9, 1913); *Min. Ind. 1914*, 67; Riley, *op. cit.* p. 17.
32. *Weekly Drug Mkts.* 14 (Oct. 27, 1915).
33. *Drug. Circ. 60*, 33 (1916).
34. *Min. Ind. 1914*, 70.
35. *Ibid. 1913*, 716; *1914*, 710, 713; *1916*, 695; *Min. Res. 1914*, II, 151; *1919*, II, 267.
36. *Min. Ind. 1913*, 720.
37. A. M. Spiehler, *Pharm. Era 48*, 220 (1915).

38. *Min. Ind. 1917*, 670; *1918*, 684.
39. *Chem. Met. Eng. 30*, 31 (1924).
40. *Min. Ind. 1919*, 657; *1921*, 662; *Min. Res. 1918*, II, 560.
41. *Min. Res. 1922*, II, 86.
42. *Ibid. 1914*, II, 39.
43. Bur. Mines, *Bull. No. 71* (1913); *Min. Res. 1915*, II, 9.
44. *Min. Res. 1918*, II, 135.
45. Baruch, *American Industry in the War*, p. 208; Clarkson, *Industrial America in World War*, p. 417*n*; C. H. MacDowell, to author, Sept. 25, 1943.
46. *Eng. Min. J. 107*, 70 (1919).
47. *O.P.D. Reptr.* 51 (May 6, 1918), 95 (Oct. 7, 1918); *Drug Chem. Mkts.* 21 (May 8, 1918); *J. Ind. Eng. Chem. 10*, 948 (1918); *Chem. Met. Eng. 19*, 498 (1918).
48. *Met. Chem. Eng. 20*, 327 (1919); *Eng. Min. J. 109*, 147 (1920); *117*, 99 (1924); *J. Ind. Eng. Chem. 11*, 380 (1919).

Chapter 21

CHEMISTRY TOUCHES NAVAL STORES

SHERMAN ANTI-TRUST LAW HINDERS REORGANIZED NAVAL STORES INDUSTRY—YARYAN INTRODUCES STEAM-SOLVENT RECOVERY PROCESS—NEWPORT DEVELOPS WOOD-ROSIN EXTRACTION—INDUSTRY STABILIZED BY FEW, LARGE PRODUCERS AND CHEMICAL TECHNOLOGY.

FEW AMERICAN INDUSTRIES were actually hurt by World War I. The majority were stimulated to great and rapid growth. The producers of naval stores were a conspicuous exception and the reasons are self-evident.[1]

In 1914, the American naval stores industry exported 60 per cent of its turpentine and 80 per cent of its rosin. Foreign sales had been exceptionally brisk that year, but year in and year out, since the very beginning of this oldest American industry, most of the naval stores crop had been sold in Europe, the best customers being Great Britain, Germany, and the Netherlands.[2] This great dependence upon an export trade that was completely demoralized during the war, was made more dangerous by weaknesses inherent within the industry itself and also by outside influences over which the naval stores producers themselves had little or no control.

The economic vulnerabilities of an industry composed of some 1,500 small, independent producers operating on leased trees are obvious. The usual terms of such leases cover a specified number of gum-collecting cups at an agreed rental fee per crop per year. A crop is reckoned as 10,000 cups or cut faces, which yield on the average 36 barrels of 50 gallons each of turpentine and 120 barrels of 500 pounds each of gum rosin. The average for a fair season is about 6.5 pounds of both products per cup.[3]

Bound by nature to seasonal production, which always promotes crop-to-crop price fluctuations, the output of so many small operators naturally varies considerably from year to year. Thus a seasonal market is rendered unusually unstable. To this uncertainty of price have always been added extreme variations in quality. This is inevitable in the collection of a natural product, worked up in a multitude of little stills operated with all possible degrees of skill and care. The 15 distinct color grades of rosin recognized in the trade were evidence of this unsatisfactory basic condition of the business.

These fundamental difficulties had always influenced the naval stores market, but unfortunately the war in Europe broke out at a time when the marketing machinery of the industry was badly disorganized. In 1913 the American Naval Stores Company, through which admittedly 75 per cent of the exports were handled, was selected by the Attorney General to make a good test case under the recently enacted Sherman Anti-Trust Law. As a result, the Company was forced to suspend business in a voluntary bankruptcy action, March 17, 1913.[4] The whole trade was thrown into confusion, and before it recovered, ocean shipping was disrupted by British cruisers vigorously scouring the seven seas during the opening stages of the war.

Later, naval stores shipments abroad were made exceedingly difficult by embargoes and contraband orders, by the British blockade, and finally by the acute shortage of cargo space. As a result of this loss of foreign outlets, naval stores prices slumped—an almost unique phenomenon—and they only advanced after world markets were reopened, so that during the sharp depression of 1920 they went a second time counter to the general trend of commodity values.[5]

Out of these many evils came some good. A measure of cooperation was forced upon this individualistic, decentralized industry. Its primitive, wasteful technique simply had to be revised and the enlivening touch of chemistry modernized both the production and the utilization of all pine products.

The effects of the Government's anti-trust suit against the American Naval Stores Company * were sensationally disastrous. Ever since this consolidation had first been effected, back in 1906, it has been popularly dubbed "the Naval Stores Trust" and no secret was made of its control over the sale of more than half of the country's output of rosin and turpentine. The corporation had been prosecuted under the old Clayton Act and had won. The new suit was carried to the Supreme Court frankly as the first test case to determine the constitutionality of the criminal provisions of the Sherman Anti-Trust Law, a leading feature of the liberal legislative program sponsored by President Wilson.

In the lower Federal Court, although the parent corporation and its subsidiaries were the principal defendants in the case,[6] only the officers were indicted. The Company entered a general denial of combination in restraint of trade and specific denials of a trade war against the Naval

* The other defendants in this case were: American Naval Stores Co., N. Y.; National Transportation & Terminal Co., N. J.; National Transportation & Terminal Co., N. Y.; Peninsular Naval Stores Co., Fla.; Union Naval Stores Co., W. Va.; Edmund S. Nash; Spencer P. Shotter; J. F. Cooper Myers; C. G. De Loach; George M. Boardman; and Carl Moller. (See *O.P.D. Reptr.* 9, Jan. 15, 1912.)

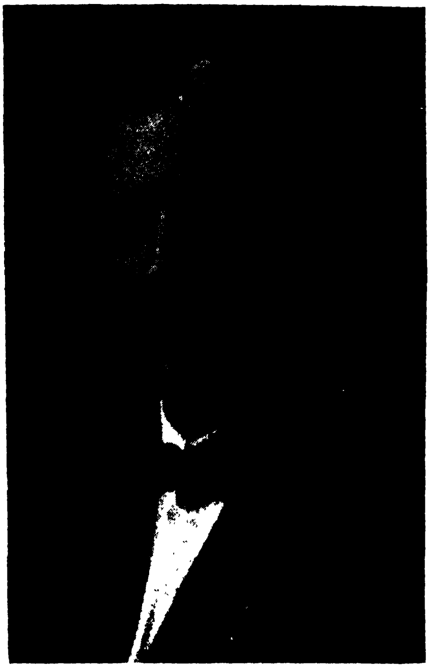
Stores Export Company and manipulation of the Savannah market. For its defense it pointed out that on September 27, 1910, prior to the filing of this suit, it had offered its books and contracts for inspection by the Department of Justice.[7] The Supreme Court ruled that there had been a mistrial, due to improper instructions by the presiding judge, and ordered another trial.[8] On June 1, 1914, the United States District Court acquitted the officers, the jury having been instructed to consider the charge of restraint of trade only, since the evidence offered was insufficient to sustain the charges of diverting receipts to depress markets, of boycotting, and of giving improper bonuses.[9]

Thus ended six years of bitterly fought litigation. But the bare facts above tell only a small part of the story. The dominating position of the American Naval Stores Company in the market was never denied, and everyone in the trade knew what great influence it wielded. The appearance of monopoly was perfect. The case of the Attorney General was a sound, sincere effort to protect both the individual producers and the public. It ignored, or possibly failed to comprehend, that the inherent nature of the naval stores industry rendered such a monopoly as it conceived of as in restraint of trade, utterly untenable.

As a matter of practical reality, a strong, centralized marketing organization which could stabilize prices was to the advantage of both producers and consumers. However great its influence, it could never establish an effective monopoly unless it controlled most of the 1,500 sources of supply. S. P. Shotter, Edmund Nash, and their associates were far too wise in the ways of turpentine and rosin to attempt so foolhardy a scheme. They knew that even if they tied up all producers with contracts, a hundred dollars and a couple of Negro workers were all that a new "gum farmer" needed to go into business, and he could even set up a "turps still" for only three times this modest investment. If their alleged monopoly attempted to exercise its traditional prerogative to raise prices unduly, a new swarm of producers would be quickly attracted to their jam-pot; overproduction would flood the market; their monopolistic price would be swamped.

So far as any valid monopoly was at issue, the Government was attacking a strawman, a phantom so ephemeral that it vanished suddenly before their eyes. Mere entry of the anti-trust suit was sufficient to precipitate such serious financial difficulties that within a month the officers of the American Naval Stores Company resigned, the creditors took over, and a committee of five bankers was appointed to administer the affairs of this menacing giant.[10] The first act of that committee was to borrow $750,000 from the creditors themselves.[11] A month later,

J. F. COOPER MYERS



CARL MOLLER

T. ALBERT JENNINGS

A. K. SESSOMS

May 1913, the Company was reorganized.* Ten months later its assets were sold to the Standard Naval Stores Company, recently organized by the old corporation's vice-president, J. F. Cooper Myers. To cap the climax, this Standard Naval Stores Company went into voluntary dissolution January 1, 1915, due, so it was announced, to lack of business because of adverse war conditions.[12]

At the very time the Attorney General was suing the Naval Stores Trust to protect the little independent producers, he was petitioned by a delegation of these same small operators, representing 85 per cent of the current crop, not to prosecute them under the Sherman Law if they banded together in a combination which they assured him was "the only plan to save the industry from ruin." [13] Under the impact of the war the prices of rosin and turpentine had collapsed, and quite innocent of any ironical implications, they proposed to establish the closing quotations of the Savannah Board of Trade as of July 31, 1914, as a base to be maintained by a selling pool which would refuse to sell anyone any of their products below these pegged figures. If granted immunity from prosecution as a trust, the producers promised "at the end of the war, or at such time as the market rights itself, to dissolve this pool and let naval stores sell at true figures as determined by supply and demand."

The Attorney General indignantly rejected this proposal. He must have been deeply touched, for he promised to act immediately and vigorously against the slightest infraction of the Sherman Law.[14] But he did not make good this threat. In fact he did not have to, for while the pool was organized and within a month claimed control over 95 per cent of the season's production, nevertheless, it dissolved completely within the year and without being able materially to stiffen the sagging market.

The Turpentine Farmers' Association,† organized in September 1914 to operate this pool, naturally fell apart when its objective was not reached. It was the forerunner, however, of another organization which, with more reasonable aims, did a great deal of good cooperative work. This was the Turpentine & Rosin Producers' Association, organized January 23, 1917, with headquarters at New Orleans. The first officers were L. N. Dantzler, president; J. A. Taylor and H. H. Gordon, vice-presidents; Carl F. Speh, secretary-treasurer.[15] The fol-

---

* The new officers were M. A. O'Byrne, pres.; Mills B. Lane, vice-pres.; O'Byrne, Lane, Lewis B. Franklin, Pierre Jay, F. D. Bloodworth, T. M. Cunningham, Jr., H. A. Schrader, W. H. Crawford, J. E. Driscoll, and A. F. K. Mustin, dir. S. P. Shotter and J. F. C. Myers had resigned as chairman and vice-pres., respectively. (See *O.P.D. Reptr.* 11, May 5, 1913.)

† A. Sessoms of Bonifay, Fla., pres.; T. A. Jennings of Pensacola and J. S. Shinglu of Ashburn, Ga., vice-pres.

lowing autumn the Association sent a committee to Washington to confer with the National Defense Council and the Department of Agriculture. Ruinously low prices prevailed and the adulteration of turpentine and misbranding of rosin had become common enough to threaten the already weak price structure. The dangerous demoralization of the naval stores trade was not news in Washington. However, as Carl Speh pointed out, this frank discussion did make clear that the industry itself must take bold defensive measures to stabilize market values.[16] Meetings of producers and dealers, which government officials attended, were held at New Orleans, Savannah, and Jacksonville. An official trade-mark was adopted to be used by members as a hallmark of guaranteed quality. New uses for rosin and turpentine were discussed and plans for a cooperative advertising campaign drawn up.[17]

The Department of Agriculture was sympathetic, but direct cash subsidies and ceiling prices were as yet undreamed-of forms of relief, so there was little that could be done officially. As far back as 1914, the Department had held hearings on the standardization of naval stores and Congress had appropriated $5,000 for an investigation in the field.[18] To further this laudable endeavor, the Bureau of Chemistry designated definite shades for the various grades of rosin and prepared colored slabs of glass—standards made up in conformity with the Lovibond tintometer scale—to be used for official testing and grading.

Within two months, the New York Produce Exchange and the Boards of Trade of Savannah, Jacksonville, New Orleans, Brunswick, Mobile, and Pensacola—all the open markets that counted—had adopted these official standards,[19] and in September 1916, when Congress appropriated an additional $10,000 for naval stores investigations, part of this was spent for more sets of these glass standards. Most of this money, however, went to study wastes in the industry, which it was estimated then accumulated a $3,000,000 loss every year.[20] The Bureau of Chemistry also defined four official types of turpentine and set up similar color standards, while throughout 1917, trained field agents toured the South, training operators in the approved techniques of collection and recovery and preaching cleanliness as the best means of raising the grade of pine products.[21]

Naturally a cure of the naval stores industry's ills by law was proposed. Producers, traders, and government officials joined in backing a bill introduced by Representative Pat Harrison of Mississippi and Senator Warren G. Harding of Ohio, providing for official inspection and grading of all naval stores entering into interstate commerce.[22] Swamped with war activities, Congress paid scant attention to this bill which died in committee. It was periodically reintroduced, but not until 1923 was the first federal Naval Stores Act passed and approved.

Labor and transportation difficulties also piled upon the heavily laden shoulders of naval stores producers. Somewhat better allocation of available shipping facilities, especially to consumers with war contracts, came after the Government took over the railways. On the other hand, the labor situation deteriorated and was injured by official action. High wages in war industry plants were drawing cheap Negro labor out of the Southern states. The Government recognized this problem as a serious one for the cotton planters, but gave scant attention to the needs of the naval stores producers.

Cliff Williams, United States Labor Commissioner for Georgia, Florida, Alabama, Mississippi, and Louisiana, covering almost all the naval stores producing area, announced that he considered rosin and turpentine nonessential products and that the Government would have to use labor engaged in their production elsewhere. This aggravated an already serious situation. A further exodus of workers followed this thoughtless statement and a speculative flurry temporarily boosted naval stores prices. This rise in their costs naturally drew protests from the paint, varnish, and linoleum manufacturers, many of whom were making goods for the war effort. Williams called the naval stores people to New Orleans on June 10, 1917, to explain his position.[23] He recanted—he had not meant what he said at all—and gave the bureaucratic explanation that he merely wanted better cooperation.

"Scare 'em," he was quoted as having said, "by letting them think you are going to take everything, and they'll give you all you ask."[24]

An easy prey to many economic dangers, the naval stores industry was helped, not by well-intentioned government activities, but by chemical technical developments. In retrospect, we can now see clearly that official interference did not assist producers, but on the contrary initiated a course of government action which has since proved almost disastrous. The sole constructive move was the setting up of official standards, a logical function of the Government, while the subsidies and controls later employed, often at the behest of the producers, themselves, have proved powerless to fend off the competition of lacquers and synthetic resins with paint and varnish. These new chemical products cut deeply into the naval stores demand and were only offset by the development of rosin and turpentine as chemical raw materials. This chemical line of progress had been initiated several years before the war, and as Dr. John E. Teeple pointed out,[25] it was fostered in four different directions by chemical research:

1. Improving the quality and increasing the quantity of rosin and turpentine recovered from the living tree—the work of Dr. Charles H. Herty.
2. Discouraging adulteration by providing definite standards—the work of the Bureau of Chemistry.

3. Enlarging the markets by finding new uses for rosin, largely through chemical modification and by employing turpentine as a raw material for chemical synthesis, as in synthetic camphor—the accomplishments of a great many independent researches.
4. Utilizing the rich, dead pine wood and stumps for the production of naval stores—the work chiefly of Newport Industries and Hercules Powder Company.

Sweating pine products out of wood and stumps was not exactly a new discovery. It had long been practiced in primitive charcoal pits, the main product being thick, viscid pine tar. Shortly after the turn of the century, however, it began attracting men who envisioned a new industry. The idea was especially alluring because already signs indicated that lumbering activities and careless tapping of the living pines were in a wicked conspiracy to destroy the source of all naval stores. The Department of Agriculture furthered these ideas by officially forecasting the end of the gum naval stores supplies. Sincere enterprisers in this wood naval stores business were joined by slick promoters who began selling stock in flimsy corporations to gullible investors. Most of these early wood-extraction processes depended upon steam or destructive distillation. They produced no rosin. Accordingly, when the turpentine market collapsed in 1909, several score of these new plants closed up. At this time, too, the demand for rosin was growing fast, a fundamental change in the naval stores industry which profoundly upset its traditional practices and prices.

Just at this time a vivid character stepped into the picture. Homer T. Yaryan, an inveterate inventor who had made money out of his patented sectional bookcases, built an experimental plant in Michigan to test his process for a combined steam and solvent recovery of rosin and turpentine from pine stumps.* Having proved this out to his own satisfaction, he built a larger plant at Gulfport, Mississippi.[26] This was in 1909 and that year he produced 14,307 barrels of rosin, 1,790 barrels of turpentine, and 700 barrels of pine oil. Three years later he built a larger plant at Brunswick, Georgia, but his Yaryan Naval Stores Company ran into financial snags and in 1914 was put up for sale by court order.[27] Yaryan, always an energetic optimist, managed to raise additional capital, and in 1915 organized the Yaryan Rosin & Turpentine Company, which acquired the plants of his bankrupt enterprise.[28] The Brunswick plant, which the new company began to operate, was gutted by fire on March 17, 1916, but the Gulfport plant was promptly put into production.[29]

While the colorful Yaryan—he smoked long, black cigars incessantly and swore like a stevedore—was thus struggling, others were brav-

---

* See Appendix XLVI for Yaryan's own account of his chemical ventures.

Gulfport Plant of the Yaryan Naval Stores Co.

Pensacola Plant of Newport Industries, Inc.

ing the technical difficulties and unfavorable market conditions that clouded the youth of this new industry. One of these was to persist to eventual success. In 1912 the Newport Rosin & Turpentine Company was incorporated at Bay Minette, Alabama, for $100,000, by H. J. Schlesinger, A. A. Schlesinger, and Wilmot Saeger.[30] In the early 1900's Hugo Schlesinger owned and operated the Vera Chemical Company, which produced a patented size for paper at North Milwaukee, Wisconsin. He was a member of the family that controlled the Milwaukee Coke & Gas Company, which during the war played so important a part in establishing the American dye industry. Being shrewd and chemically minded, he wanted to find a second source of rosin. He was approached by W. B. Harper who knew of a process for extracting rosin from pine stumps and waste wood. Ferdinand Schlesinger arranged with Harper to build a plant for this purpose at Bay Minette in 1912. A contract was made with the Bay Minette Land Company, large holders of cut-over land in Baldwin County, Alabama, which provided that Newport could remove the stumps from this cut-over land at no cost, as the land company was interested in developing the property for farming. W. B. Logan, a chemist from the coke plant, went down to operate the plant in 1913. He later sent for Al James, a mechanic at the coke plant. Between the two of them, they got the plant in operation on a fairly successful basis by early 1915.

It soon developed that the dark rosin which was extracted was not suitable for making light-colored paper size. Turpentine and pine oil were found to be by-products of this rosin operation. Sales of these products were very slow, and a stock of 14,000 or 15,000 barrels of rosin soon accumulated at Bay Minette. The plant had a capacity of about 70 tons of wood per day. With the advent of World War I, a market became available for the rosin and the entire stock was sold. C. N. Turner, who was in charge of sales at that time, interested some of the railroads in using the turpentine. This product was not at all competitive with gum turpentine, since it was very bad-smelling, and there was tremendous prejudice against its use. Some early markets existed for pine oil, but apparently pine oil at that time was not much of a marketing project.

In late 1915 the Schlesingers decided to build another plant. Logan was sent to Brunswick to look over the old plant of the Yaryan Company. He recommended against buying it and was told to seek another location and to arrange for the building of a new plant. They selected Pensacola and the engineering on the new plant was begun in late 1915, actual erection starting in the spring of 1916. By the end of 1916 it was in operation with a capacity of about 150 tons of wood per day. A contract was made with the Southern States Lumber Company, large owners of cut-over land in Escambia County, Florida, and the stumps for the new plant were procured from this source. The Bay Minette and Pensacola plants were operated during 1918, 1919, and 1920. In 1921, on account of the severe business depression, both shut down all that year.

Chemical work started at Pensacola in 1916, when R. C. Palmer was installed as the chief chemist. He had had previous experience in wood by-products chemistry at the Forest Products Laboratory at Madison. During those earlier years, practically all of the chemical research was devoted to improving the three products and standardizing methods of operation. However, in 1920, a complete process was developed for the production of chemicals from pine oil, but it was abandoned in 1921 because of the depression. Afterwards the market for pine oil was fairly good for a number of years, and it was not until 1935, when the Oxidation Products Company was acquired, that the production of chemicals from pine oil was put into operation.*

After the close of the war, two other companies that had some lasting effect upon the development of the new wood-rosin industry began operations: the Mackie Pine Products at Covington, and the Acme Products Company at De Quincy, Louisiana. In 1920 the Hercules Powder Company began building a wood-rosin plant at Hattiesburg, but before this was completed, it bought out Yaryan and took over his plants at Brunswick (which had been rebuilt) and Gulfport.

The sudden postwar revival of interest in the extraction of naval stores from wood was grounded upon two apparently sound bases. The rosin and turpentine market had emerged from the doldrums of restricted exports, and the price of turpentine doubled and rosin quadrupled.[31] Everyone was certain the day of cheap naval stores was past. Lumbering had greatly expanded during the war and the depletion of the Southern pine forests was more evident than ever before. Senator Arthur Capper of Kansas, an old champion of the conservation of our natural resources, obtained additional federal funds for an investigation, but the findings were exceedingly gloomy. The Department of Agriculture again began crusading for the preservation of this old industry with so important, world-wide sales.

The establishment of the wood-recovery process seemed most propitious. It was, at the time, admittedly higher in costs and its products were low in quality. There was every reasonable prospect, however, that prices would not slump and that the competition of the gum producers would steadily weaken. Improvements were bound to come in

---

* I am indebted to Seymour J. Spitz, vice-pres., Newport Industries, for the facts of the Company's early days and first developments. (W. H.)

the new process, that would make it more efficient and so improve its products that the prejudices of the trade would be overcome.

Following this line of reasoning to its logical conclusion, the management of the Hercules Powder Company, which was seeking to broaden its strictly explosives base with other chemical products, determined to go into the wood-rosin business. The assumptions upon which this decision was made all proved misleading. Chemical developments, notably lacquers and synthetic resins, as we have noted, cut down the consumption of turpentine as a paint solvent and of rosin as a varnish ingredient. Naval stores prices did come down again. Even the extinction of the pine forests failed to materialize. In fact, so easily did the long-leaf pine reseed itself on cut-over land and so quickly did it grow that, far from a curtailed supply, the practicability of increased output was distressingly obvious.

Not dismayed by this unforeseen twist of affairs, both Newport and Hercules settled down to overcome these handicaps. From collecting stumps in the field to packaging the finished products, each operation was subjected to thoroughgoing investigation. Every phase in the distillation process was studied and studied time and again. Research was directed to improving the quality of every product. The comparatively neglected chemistry of the oleoresins of pines was explored as never before. This formidable task of almost literally remaking the country's oldest industry upon a modern chemical basis was not accomplished in a day. It had only begun in 1922; but a start in the new direction had then been definitely initiated.[32] From 1920 onwards progress, if slow, was steady.

Another slow-maturing technical development was born during the closing years of the war period. The recovery of turpentine and tall oil from pine wood used in the sulfate pulp-cooking operation had been successfully practiced in Norway and Sweden since the opening of the century. The growth of the kraft paper industry in the Deep South brought with it an interest in this process. Experimental work was seriously undertaken in 1917, but the commercial development had to await the finding of markets for the principal product, the dark, smelly mixture of rosin and fatty acid soaps called tall oil or liquid rosin.[33]

The grueling market conditions of the war naturally took their toll, and failures and reorganizations, especially among the exporting firms, marked these years. The downfall of the powerful American Naval Stores Company had numerous repercussions. Out of the old Jones-Dusenbury Company came the Globe Naval Stores Company, incorporated in 1913 under the laws of Alabama.[34] The president was T. Albert Jennings, one of the best-known naval stores men in the South, president also of the Jennings Naval Stores Company, and for years a member of the Florida legislature and president of the Senate.[35] This same year the Rosin & Turpentine Export Company of Savannah was organized by J. W. Motte, J. A. C. Carson, and J. E. Harris. Originally incorporated for $1,000,000, this capitalization was reduced to $300,000 when in 1916 the company was reincorporated by Carson, Motte, H. L. Kaytor, and W. A. Coachman.[36] This company was sole distributor for the Atlantic Turpentine & Pine Tar Company, one of the biggest, best-equipped producers, and the next year, when Edmund S. Nash, formerly president of the defunct American Naval Stores Company, became president and general manager, he brought with him as selling agents for the Eastern states and Canada, the strong firm of Robinson & Stevens.[37]

A distinguishing characteristic of this period was the increasing size of both producing and distributing companies. For example, the Columbia Naval Stores Company, dealers of Chicago, incorporated in 1916 for $1,000,000; among the producers, the Southern Pine Products Company and the Farley Pine Products Company both had $300,000 working capital.[38] The darky-with-an-axe phase of turpentine farming was passing. The individual broker, who operated upon a personal basis, was being replaced by incorporated sales organizations.

These tendencies towards centralization were quite in line with what had been happening throughout all American industry since the close of the Civil War. They reached this highly individualized field late, but they exerted great influence. Fewer producers operating larger, better-equipped stills, gave the naval stores market greater stability and raised the average grade of rosin and turpentine. Both the example and the competition of the big wood-rosin companies suggested the advantages of chemical control and possibilities of a greater chemical utilization and diversification of pine products. Individual farmers were quite unable to act upon these plain hints, but larger-producing units could at least try to do so. During the 1920's many did install modernized equipment and experiment with new chemical ideas.

REFERENCES

1. Primary sources of naval stores during the war, A. W. Schorger and H. S. Betts, Dept. Agr. *Bull. No. 229* (1915); F. P. Veitch and V. E. Grotlisch, *ibid. No. 898* (1921); J. M. Peterson, *J. Chem. Educ. 16,* 203, 317 (1939); E. V. Romaine, *Chem. Ind. 45,* 259, 402 (1939).
2. Tariff Comm., *Tariff Inform. Surv., No. AFL-17,* 35-52 (1921). See also Appendix XLV for 1912-23 exports and production of naval stores.
3. Romaine, *op. cit.* p. 406.
4. *O.P.D. Reptr.* 11 (Mar. 24, 1913).
5. War Ind. Bd., *Price Bull. No. 51,* 6 (1919).
6. *O.P.D. Reptr.* 11 (Mar. 24, 1913).
7. *Ibid.* Pt. 1, 11 (Mar. 10, 1913).
8. *Ibid.* 18 (Feb. 2, 1914).
9. *Ibid.* 11 (June 8, 1914).

10. *Ibid.* 11 (Mar. 31, 1913).
11. *Ibid.* 11 (Apr. 21, 1913).
12. *Ibid.* 41 (Mar. 16, 1914); 18 (Dec. 14, 1914).
13. *Weekly Drug Mkts.* 10 (Sept. 23, 1914).
14. *O.P.D. Reptr.* 16 (Jan. 29, 1917).
15. *Ibid.* 40 (Nov. 12, 1917).
16. *Ibid.* 31.
17. *Ibid.* 32H (Mar. 9, 1914; 19 (July 13, 1914).
18. *Ibid.* 32E (May 10, 1915); 32F (June 21, 1915); *Weekly Drug Mkts.* 21 (June 23, 1915).
19. *O.P.D. Reptr.* 33 (Oct. 2, 1916).
20. *Ibid.* 16 (Jan. 8, 1917); 33 (Jan. 15, 1917); 17 (Sept. 24, 1917).
21. *Ibid.* 33 (Mar. 5, 1917); 33 (June 11, 1917).
22. *Ibid.* 27 (June 10, 1918).
23. *Ibid.* 27 (June 24, 1918).
24. J. E. Teeple, *J. Ind. Eng. Chem.* 7, 931 (1915). See also H. C. Morris, *Chemicals* 5 (Aug. 3, 1925).
25. Haynes, *This Chemical Age*, pp. 150, 154.
26. *O.P.D. Reptr.* 36 (Feb. 23, 1914); 34 (Apr. 13, 1914).
27. *Ibid.* 11 (Aug. 23, 1915).
28. *Ibid.* 15 (Mar. 20, 1916).
29. *Ibid.* 27 (May 6, 1912).
30. E. H. French and J. R. Withrow, *ibid.* 18 (Mar. 23, 1914); *Ind. Eng. Chem. 21*, 1300 (1929); *Chem. Mkts. 27*, 592 (1930).
31. Haynes, *op. cit.* p. 155.
32. *Ibid.* p. 157; F. E. Greenwood, *Paper Trade J.* 60 (Feb. 3, 1926), 52 (Feb. 10, 1927).
33. *O.P.D. Reptr.* 76B (Dec. 10, 1917).
34. *Ibid.* 11 (May 26, 1913).
35. *Ibid.* 14 (Sept. 3, 1917).
36. *Ibid.* 63 (Aug. 4, 1913); 24 (May 22, 1916).
37. *Ibid.* 14 (Apr. 2, 1917); 15 (May 7, 1917); 15 (July 3, 1916).
38. *Ibid.* 16 (May 28, 1917); 20 (July 10, 1916); 40K (July 24, 1916).

Chapter 22

CRUDE DRUGS

AGRICULTURE EXPERIMENT STATIONS AND COLLEGES OF PHARMACY PROMOTE DRUG-FARMING—GROWING OF LICORICE, BELLADONNA, DIGITALIS, ETC., FLOURISHES—CELLULOID AND DU PONT FAIL TO ESTABLISH CAMPHOR IN FLORIDA—CRUDE DRUG MARKET HIGHLY UNORGANIZED AND SPECULATIVE—ONLY NATIVE DRUGS SURVIVE POSTWAR SLUMP.

BARKS, berries, roots, leaves, blossoms, balsams, gums, waxes—some 400 distinct items, not counting many botanical varieties and almost numberless trade grades—are important raw materials of the medicinal chemicals, the pharmaceutical and proprietary, the food, chemical specialties, and other industries. This multitude of crude drugs comes from every section of the globe. Since the great majority are imported, World War I profoundly upset their supply. Critical shortages and sensational price advances occurred within this group.

Drugs connote medicines, but the uses of crude botanical drugs are bewildering in their scope, almost fantastic in their variety. Licorice, for example, was during this period the top number of the drug trade; "top," that is, from the point of view of more bulk weight—in 1913, 105,032,429 pounds[1]—most of which went to flavor plug chewing tobacco. Confectionery was a good second consumer and medicine a rather poor third. Imports dwindled till in 1918 they totaled only 27,051,021 pounds. From a normal prewar quotation of 4½¢ the price climbed to a peak of 34¢ in May 1918.[2]

Licorice root comes from the Mediterranean countries, chiefly from Turkey, but during the war our principal supplier became Spain. In circumventing short supplies at the original collection centers and shipping stringencies, the imports of Spanish licorice extract in the form of paste and dried rolls virtually doubled: from 832,277 pounds at $106,288 in 1913 to 1,702,927 worth $230,129 in 1916.[3] The licorice plant thrives in many sections of the United States, and even before the war efforts were made to establish its commercial cultivation in California. As the Tariff Commission officially reported, "grown here more or less experimentally, but the cost of harvesting precludes commercial production."[4] And yet, at the height of the war shortage in the spring of 1918, a company was organized to grow licorice on 1,000 acres of the New Jersey pine-barren lands.[5] The MacAndrews & Forbes Company experimented for seven years and spent $526,000 in an unsuccessful attempt to grow licorice root in New Jersey.[6]

This synopsis of the war story of licorice is very like that of hundreds of other crude drugs. Throughout the regions of their usual commercial origin the supply was greatly reduced. In the Mediterranean countries and the Near East, the most important drug-producing sections of the whole world, drug cultivation was forsaken for much more profitable food crops. Throughout Europe, Russia, China, and India this same agricultural change took place. In Belgium and the north of France the battling armies tramped over fields of chamomile, valerian, and digitalis, which suffered not only from boot-heels but also from neglect.[7]

War demands soon stripped bare the stocks in the great drug markets of London, Hamburg, and New York. At the primary markets scattered all over the map, not only were accumulations scanty, but as the war progressed it also became increasingly difficult to charter ships to transport what small stocks had been collected. Little wonder that prices soared. After we entered the war the Army-Navy demands for medicinals simply swamped the New York market. To secure the enormous supplies needed, it was necessary to adopt the system of competitive bidding on monthly lists in order to spread the buying and distribute the orders among many manufacturers. From one such monthly list, the following items give some idea of the drug requirements: compound cathartic, 32,000,000 pills; codeine sulfate, 8,000,000 tablets; morphine sulfate, 9,500,000 tablets.

For many Americans a coaxing fascination seems to lurk in the idea of growing medicinal plants. War shortages with accompanying war prices have always enlisted an army of amateur drug growers. But this interest is not wholly a practical expression of the gardening hobby. Since colonial times the commercial cultivation of drugs, spices, dyes, and perfume flowers has inspired government officials, medicinal manufacturers, even hard-headed dirt farmers to all sorts of experiments.[8]

The opening years of this century witnessed a lively revival of this interest. It was a period of world-wide botanical exploration, avowedly to find new horticultural species for gardens, new food plants for farms, new natural drugs for medicine. In 1903 one of the world's great plant hunters, David Fairchild,* had organized the division of the

---

* Son of a prof. at Mich. State Agr. Coll., he studied at Kan. State Agr. Coll. and did postgraduate work in botany at Naples, Breslau, Berlin, Bonn, and the Botanical Gardens in Java. As asst. to Barbour Lathrop, he made four trips seeking new economic plants, and later led many expeditions to various parts of the world. Many scientific

Department of Agriculture now known as the Division of Plant Exploration and Introduction. That same year the distinguished English plant explorer, Ernest Wilson, came to this country to be active head of the Arnold Arboretum in Boston. All sorts of thrilling botanical ideas were in the air; experimental gardens were established at many points; numerous new crops were being introduced.

In the world of drugs Dr. Henry Hurd Rusby had but recently returned from the second of his four medicinal-plant explorations of South America, and the New York Botanical Gardens established its Economic Museum of which he was to become honorary curator.* Much of the interest in drug cultivation was inspired by the infectious enthusiasm of Dr. Rodney H. True† who at this time was plant physiologist with the Department of Agriculture. Accordingly, when we were cut off from imported crude drugs, there were already established here a number of experimental gardens with some practical experience and considerable plant material.

The Department of Agriculture had four of these testing grounds. The largest was at the Arlington Experimental Farm, where during 1912 some 200 medicinal species were being propagated and observed. At Timmonsville, South Carolina, special studies were carried forward on cascara sagrada and capsicum. As a result of these latter experiments, neighboring farmers grew and marketed during that season 75,000 pounds of these African peppers. Camphor, volatile-oil plants, and Oriental aromatic grasses were all being grown at the Experiment Station at Orange City, Florida. This Orange station did not last long, as the location proved to be rather unsuitable, and the work was moved to Orlando in charge of S. C. Hood.

At Madison, Wisconsin, the Department of Agriculture was carrying on extensive cultivations of wormwood, goldenseal, coriander, horehound, fireweed, and various mints.[9] The Wisconsin Experiment Station and College of Pharmacy cooperated here and Madison became an important center of this work. The University of Minnesota College

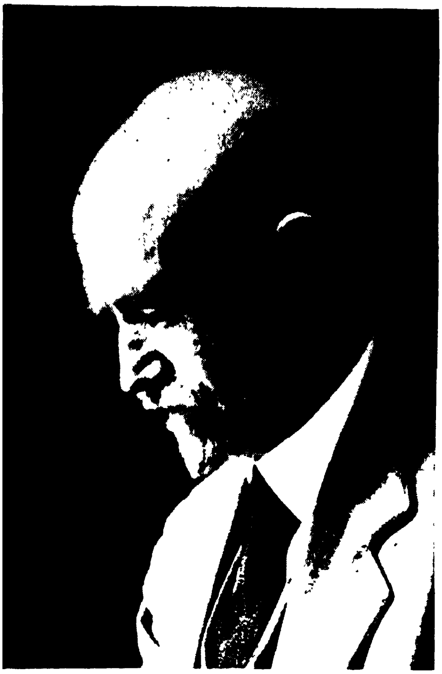
---

awards were made to him and the Fairchild Tropical Garden at Coconut Grove, Fla., has been established in his honor. He married the daughter of Alexander Graham Bell, inventor of the telephone, and retired in 1935. For firsthand accounts, see his own books, *Exploring for Plants* (1930) and *The World Was My Garden* (1938).

* Born in Franklin, N. J., Apr. 26, 1855, Rusby celebrated his 21st birthday by winning a gold medal at the Phila. Centennial Exposition, for a collection of plants from Essex Co., N. J. Having studied medicine, he explored the Southwest and later S. A. for medicinal plants for the Smithsonian Inst. For many years he was prof. botany and materia medica at N. Y. Coll. Pharm. and dean of the faculty. He served on the 7th, 8th, 9th U.S.P. Revision Comm. and his works on pharmacognosy and medical botany are standard texts. He died Nov. 18, 1940. (See his *Jungle Memories*, 1933.)

† True was later prof. botany, U. Penn. and dir. of its famous Morris Arboretum. He was prime mover in the Allegheny Forest Exp. Sta., where much good work has been done on native crude drugs. He died Apr. 8, 1940.

HENRY H. RUSBY



RODNEY H. TRUE

W. W. STOCKBERGER

CHARLES L. HUISKING

of Pharmacy was also active. In 1911 it received a grant of 40,000 square feet of land which was ploughed and planted in 1912 with 58 varieties of seed, 30 of which germinated. This was the beginning of what was to become one of the most persistent and successful drug-growing experiments in the country.[10] Another center of activity was the Pacific Northwest, a region whence came a number of wild, native plants. At the University of Washington, for example, a drug garden was started in 1915 under the direction of C. W. Johnson, dean of the College of Pharmacy. Here the cultivation of ginseng, peppermint, orris, fennel, stramonium, tansy, chicory, and especially digitalis (foxglove) and belladonna (deadly nightshade) was essayed.[11]

The Government and colleges of pharmacy were not alone in this field. A number of pharmaceutical manufacturers and even wholesale drug houses went in for drug-farming. Of these commercial projects, one of the first and most interesting was the cultivation of belladonna undertaken in 1900 by Johnson & Johnson at New Brunswick, New Jersey, and in 1909 by J. Ellwood Lee Company at Spring Mill, Montgomery County, Pennsylvania.[12]

The results of these two enterprises are significant because they fairly represent the whole drug-growing movement in this country. Both firms proved not only that these plants could be raised successfully in our climate, but also that the home-grown product could be improved in the actual drug content by care and selection. The physical condition and cleanliness of the cultivated drugs were markedly above those of the usual commercial grades. Nevertheless, judged from the dollars-and-cents standard, drug-growing was not a success. Labor costs in this country were so high that they were competitively prohibitive in all crops where picking, curing, and sorting were of necessity hand-work jobs.

A few conspicuous exceptions, governed by exceptional conditions, only emphasize the economic fact that under normal American conditions drug-farming is not profitable. In Michigan, mint-growing, thanks largely to the energy and wisdom of a single family, Albert M. Todd and his two sons, Albert and Paul H., has become a well-established business. In 1912 this business was already flourishing in Michigan and western New York, and had a firm foothold in Indiana. American peppermint and spearmint oils distilled locally are standards of the trade. Wormseed (chenopodium) and wormwood oils, both grown in Carroll County, Maryland, are regularly designated in the trade as "Baltimore" grades. Ginseng, highly esteemed for centuries by the Chinese as an aphrodisiac, formerly grew wild in great profusion throughout the middle range of the Appalachians, extending westward well into the Ohio River valley. Regular exportations to

China started over a century ago and reached up to 1,000,000 pounds a year. Vigorous, careless collection had depleted native stocks. The high price of from $10 to $15 a pound—for the best roots * the Chinese paid up to the fantastic price of $800 a pound[13]—and comparative ease of cultivation made this a practical crop, and, although wild American roots were strongly favored, a profitable one. Goldenseal (hydrastis), another native, was often grown by planters of ginseng, and during the war a single grower, working but a half-acre plot at Douglas, Allegan County, Michigan, reported having sold in one season 500 pounds of roots and thousands of live plants to prospective growers.[14] At the time of the war, both ginseng and goldenseal were cultivated rather extensively upon a thoroughly commercial basis.[15]

Soaring war prices touched off a drug-farming boom. In those exciting days, Dr. True and his able assistant, Dr. W. W. Stockberger, were kept as busy awakening impractical dreamers who visioned a quick and easy fortune from a backyard garden, as they were advising firms and individuals whose projects had some semblance of reason. Naturally most of the effort was expended upon staples of the trade, drugs in big, steady demand that had previously been imported. Belladonna and digitalis were leaders.

The former had already attracted drug growers, and during the season just preceding the outbreak of the war, a shipment of American-grown belladonna from a plantation near Haywood, California, was the first transaction of this kind in the Western Hemisphere.[16] By 1917 digitalis was so critically scarce that the Council of National Defense not only urged pharmaceutical manufacturers to grow their own supplies, but also called upon women's clubs, school teachers, and others to gather the wild foxglove that grew in West Virginia, Washington, and Oregon.[17] So successful were these efforts that at the time of the Armistice both these important drugs were in oversupply. What might well have developed into a substantial addition to American drug-growing was thus crippled by abnormally low prices which persisted for several years thereafter, discouraging domestic cultivators.[18]

Rapidly growing use of camphor as a plasticizer in the pioneer nitrocellulose plastics and the merciless rigging of prices by the Japanese, who enjoyed a natural monopoly of this gum from Formosa, incited both the Celluloid and Arlington companies to undertake its cultivation in this country in the early 1900's.† In the prewar years the price of

---

* "Best" in the Chinese trade meant tubers whose shape simulated that of the human body.

† For firsthand data I am indebted to W. S. Landes, who wrote a special memorandum on the Celluloid experiments, and to Lammot du Pont, who made available a special report by F. A. Gruder, dated Dec. 26, 1919, to the Exec. Comm., E. I. du Pont de Nemours Co. See also Landes, *Chem. Met. Eng. 35*, 524 (1928). (W. H.)

camphor in New York had ranged from 31-85¢ a pound. As their consumption increased, American plastics makers were made painfully conscious of their dependence upon a controlled, foreign supply of this basic raw material. Neither of these companies entertained any delusions about the possibility of producing the gum here upon a competitive basis, but they did seek to protect themselves. They faced a possible shutting off of their supplies and a probable advance in price to prohibitive heights by collusion between the Japanese Government camphor monopoly and the Japanese plastics makers. Theirs were not our first camphor-growing experiments, for in 1880 the Department of Agriculture had distributed seed which had been planted in eight Southeastern states.[19] In Florida, especially, the camphor trees had flourished and were used as windbreaks.

The 1906-7 files of the Celluloid Corporation revealed that the Formosan Government was reaping a very high profit from camphor, but a reaction followed in 1907, caused by German synthetic camphor and depression of world markets. Nevertheless, it was agreed to go ahead with plans to grow camphor in Florida on 3,000 acres purchased in 1907 near Lake Como in Flagler County. This purchase was increased shortly after to 5,000 acres. Some of the acreage, known as "high pine land," was very sandy and unproductive. In spite of this, however, by 1920 some 640,000 trees, ranging from one to thirteen years old, covered 1,500 acres of this Satauma plantation. The endeavor to reap camphor-bearing twigs or clippings by pruning encouraged attack by thrips fungus. Fertilization to produce a healthier growth was defeated by the poor quality of the soil, which enabled fertilizers to leach out and wash away. Moreover, the crop had a tendency to produce camphor oil instead of the fully oxidized product. These difficulties, the higher cost of labor as compared with that of China and Japan, and the promise of abundant synthetic camphor ultimately led to the abandonment of the project.

Du Pont's experience was discouragingly similar. In 1915 it took over its subsidiary, the Florida Essential Oils Company, with the Arlington Company, which was being managed by F. A. Gruder.* It owned some 1,700 acres of cut-over timberland near Green Cove Springs, Clay County, of which 4,000 acres were cleared by 1919. At this time there were 300 acres in 4-year trees, 600 in 3-year trees, and 1,000 in 2-year trees. The investment had reached $355,677.07 and cost data indicated that 70 pounds of camphor might be expected per acre at an annual charge for cultivation, upkeep, and refining of 40¢ a pound. The appearance of thrips and the more promising prospect of

---

* Vice-pres. of Arlington, and after consolidation, asst. mgr. of the Parlin Dept. of du Pont. He retired to California in 1920 and married the actress, Marjorie Rambeau.

relief from synthetic camphor prompted du Pont also to give up this project. Both these commercial ventures but confirmed the experiments started by the Department of Agriculture back in 1907 at Wharton, Texas. Here the seed had not been sown in rows, but broadcast. However, here, too, thrips so damaged the young bushes that the crop was cut down below any possibility of profitable operation. The gloomy conclusion of the Celluloid Company was summed up in reports to its board of directors:

> Had we found somewhere in the United States a forest of camphor trees as extensive and as satisfactory in its yield as the forest in Formosa, we would not have found it commercially practicable to harvest the same. The camphor of China and Japan is available only because they are provided with a very cheap, easily satisfied, grade of labor. If one thing more than another was established by our experiments at Florida, it was that camphor cannot be raised in the United States at less than one dollar per pound for crude whizzed camphor and then no consideration given to the overhead expense or to the superintendence and management.

Among the other imported drugs cultivated enthusiastically in the United States during the war were henbane, cannabis indica, aconite, stramonium, sage, gentian, valerian, and capsicum. The native pinkroot, snakeroot, and cascara sagrada, were also widely grown. It has been estimated that over $1,000,000 was invested in drug-farming, and the record shows that, with the exception of valerian and gentian, the domestically cultivated output cared reasonably for our much expanded demands.[20] For a brief period drug-growing flourished.

On the other hand, the collection of wild native drugs, an established business centered in the Appalachian uplands of Virginia, West Virginia, Tennessee, North and South Carolina, suffered badly under war conditions. The chief items dealt in were ginseng, goldenseal (hydrastis), May apple or mandrake (podophyllum), snakeroot (senega), lobelia, bloodroot (sanguinaria), pinkroot (spigelia), and the barks of wild cherry, white pine, wahoo, and slippery elm.

This irregular, unorganized trade, which harked back to the trappers who brought "Indian herbs" to market along with their pelts, began at a multitude of crossroad stores. Here local gatherers, men, women, and children, exchanged roots and barks for groceries and dry goods. It was always a haphazard business. Successful collecting depends on expert knowledge of different species and a good deal of practical experience about the right season for harvesting and the best means of curing. Prices fluctuate widely and a trader needs to be shrewd.

From the local stores the accumulated stocks moved on to what were primary markets so far as the drug trade was concerned. These wholesale dealers, often dealers also in furs, hides, tallow, and wool, were located in the cities within the irregular triangle from Bristol, Virginia, to Cincinnati, to Statesville, North Carolina. St. Louis and Minneapolis were important centers outside the Appalachian area, and the Northwest drugs, chiefly cascara, reached the market through Portland, Seattle, and Salem, Oregon. Prominent among the firsthand dealers of this time were R. T. Greer & Company of Marion, the Hamilton-Bacon-Hamilton Company and Joseph Powell Company of Bristol, Tennessee; Sulzer Brothers of Madison, Indiana; Ralph Rosenthal & Brother and Samuel Wells & Company of Cincinnati; A. F. Phillips, Wilkesboro, North Carolina; M. E. Proffitt, Johnson City, Tennessee; J. Q. McGuire & Company, Asheville, and John M. Barr & Company, Charlotte, North Carolina; and in St. Louis, Eugene Donzelot & Son and the St. Louis Commission Company. A number of the wholesale drug houses —notably the Churchill Drug Company, Burlington, Iowa; the Langley & Michaels Company, San Francisco; and Blumauer-Frank Drug Company of Portland, Oregon, also served as firsthand crude-drug dealers.

Generally these primary dealers sold their stocks to drug merchants who cleaned, graded, and milled them and distributed collected and sorted stocks to the manufacturing consumers in the drug industry. A few firms combined these functions. Allaire Woodward & Company, Peoria, and McLaughlin-Gormley-King Company at Minneapolis, were established leaders in this field, and the war period saw the rise of S. B. Penick & Company. The head of this firm, the hard-driving, hard-working S. Barksdale Penick, had started in Asheville as a primary dealer and moved to New York. By adopting the policy of handling the entire drug business from the point of collection—both here and abroad—to the final delivery of milled or processed drug to industrial consumers, he laid the foundations of what was to grow into one of the largest and strongest houses in this speculative and chancy business.

The difficulties which beset the American crude-drug trade during the war only began when supplies started to dwindle as men were drawn from the collection areas, into the Army or munition plants. This labor shortage was serious, and women and children, for lack of experience and practical knowledge, were not able adequately to replace the men.[21] Embargoes on the railways made it all but impossible to move drugs to the chemical and pharmaceutical consumers. A shortage of burlap—made from jute from India—made packing a problem. During 1916-18 a great number of smaller collectors in the country simply gave up this branch of their business and many wholesale primary dealers were forced out of business.

Since so large a proportion of our drug supplies were imported, New York naturally became the heart of the entire crude-drug trade. Here three types of dealers carried on the world-wide business: direct importers, merchants, and brokers. A good deal of indefinite overlapping as to exact status and function characterized the business. A number of importing houses, not primarily in the drug trade, but specializing in the produce of certain countries or regions, brought in considerable shipments of drugs more or less regularly. Gum tragacanth, for example, was imported by A. D. Isbetcherian, William M. Mohrmann, the Eastern Mohair & Trading Company, and other dealers in Near Eastern goods. Japanese trading companies, Mitsui, Suzuki, Iwai, Miura Shozo, Kuhara, and others such as Bridges, Neumer & Company, McKesson & Robbins, and George Uhe Company brought in camphor, menthol, pyrethrum (insect flowers), rhubarb root, and other medicinal and aromatic products from Japan and China. W. R. Grace & Company at this time had a drug department under C. W. Dare, which regularly imported from South America.

The bulk of our imports, however, were made by specialized drug dealers who operated either as brokers for foreign shippers, receiving goods to be sold on a commission basis for the account of foreign consignee, or else as direct importers who purchased goods outright at the world's primary markets. Most firms operated upon either basis according to market conditions or the custom of a peculiar trade.

Drug merchants here sometimes bought outright for their own account and sometimes from local brokers. Much purchasing was also done upon a brokerage basis. In a highly speculative market, consisting of such a multiplicity of different items of so many distinct grades, a broker in New York with firsthand knowledge of the stocks on hand —often a single shipment arriving at a crucial moment would radically change quotations—and with contacts all over the world at the primary markets, was in a position to render a real service to makers of medicinal chemicals, perfumery, pharmaceutical products, or proprietary preparations.

By the turn of the present century, the original confines of the drug trade had been much reduced. Spices, tea and coffee, the vegetable oils, and paint pigments had all gone into the hands of sharply specialized trades. Dyewoods were vanishing in the face of competition from the coal-tar colors. Tanning materials had been taken over by the chemical dealers. Even within the contracted scope of the trade there was much specialization, and the medicinal botanicals, the gums, the essential oils and other perfumers' supplies, comprised three well-marked groups.

The dean of the crude drug trade was the dapper, dignified Jesse Hopkins, whose firm, J. L. Hopkins & Company, occupied a unique position. Other veterans were James B. Horner, Jake Manheimer, Arthur Stallman, and the two sons of R. Hillier, Isaac and Richard

Chemical Industries

JESSE L. HOPKINS

JOSEPH H. BOWNE

GEORGE UHE

ALBERT M. TODD

Hillier, who in 1921 joined forces with Percy E. Anderson, to form the short-lived Hillier-Anderson Company. Other important drug factors in New York at this time were Peek & Velsor, H. R. Lathrop & Company, Nickells-Rowland Company, Lanman & Kemp, Smith & Nichols, Inc., Meht & Daniel Corporation, and S. B. Penick & Company, mentioned above. Among the prominent drug firms more or less specializing in certain lines were Francis A. Cundill and Rockhill & Vietor (Far Eastern products), MacAndrews & Forbes Company (licorice), George H. Lincks, William H. Scheel, Thurston & Braidich, Frank B. Ross Company, and Frank-Vliet Company (gums), and W. R. Greeff & Company (quinine). Outside of New York, McIlvaine Brothers in Philadelphia, one of the oldest firms in the country; and Murray & Nickell, Chicago; Allaire Woodward & Company, Peoria; Huber & Friedman, Fond du Lac, all imported and dealt in general lines of crude drugs.

Then, as now, the drug broker occupied a useful, honorable position in the trade. During the war he lost caste somewhat because of an influx of irresponsible people who jumped into the business to take advantage of upset conditions and zooming prices. But dealing in drugs is an enterprise for experts. One cannot learn its complexities overnight. Accordingly, the dealings of the war-born, fly-by-nights in this field were restricted to secondhand trade in spot stocks, and they never became so deeply involved as they did in chemicals.

In 1910 Charles L. Huisking began serving a number of out-of-town wholesale druggists as their New York purchasing agent, a business that grew steadily and expanded its field of operations. In 1917 the firm was incorporated as Chas. L. Huisking & Company, and American sales agencies were taken on for Conti castile soap, Devold cod liver oil, and other well-known foreign brands of products handled by the drug trade. Despite these ramifications, Huisking remained fundamentally a buyer upon commission for the drug trade. Among the brokers operating during the war period were Joseph Bowne, Samuel G. McCotter & Company, Alfred Stubbs, H. W. Henning & Son, H. P. Herrfeldt & Company, R. Albert Kurka, and A. M. Alison & Company. Shortly after the Armistice, George Uhe, an ambitious young man with a wide personal acquaintance in the trade, branched out for himself and started the George Uhe Company. He had been associated with Julian W. Lyon.

Contrary to the general course of prices, the crude drug market slumped badly after the war. The primary cause of this unexpected decline in values was the depreciation of foreign exchange. This enabled foreign shippers to sell their accumulated stocks at prices much below the war quotations for the slender supplies left on hand in this country. This tendency continued until the second half of 1919, when drug prices, led by saffron, Russian cantharides, henbane, Levant wormseed, Mexican vanilla, Sumatra benzoin, and insect flowers took a sharp upturn.[22] This slump temporarily affected the collection of native drugs. Gatherers were not tempted back into the business. It seriously hurt the cultivation of drugs of foreign origin. The harvesting of our native drugs revived; but drug-farming languished when the stimulus of war conditions was withdrawn.[23]

REFERENCES

1. *O.P.D. Reptr. Yearbook 1918,* 47.
2. *Ibid.* 161.
3. *Ibid.* 47.
4. Tariff Comm., *Tariff Inform. Surv. No. A-7,* 24; *No. A-10,* 22 (1921).
5. *Drug. Circ. 62,* 96 (1918).
6. A. C. Humphries, Hearings Ways & Means Comm. on Tariff Readjustment, Jan. 8, 1929, p. 412.
7. *Weekly Drug Mkts.* 16 (July 7, 1915).
8. A. Henkel, *Drug. Circ. 56,* 128 (1912); W. O. Richtmann, *J. Am. Pharm. Assoc. 9,* 816 (1920).
9. R. H. True, *Pharm. Era 46,* 128 (1912).
10. *Pharm. Era 46,* 125 (1912).
11. *Weekly Drug Mkts.* 22 (July 28, 1915).
12. *Drug. Circ. 56,* 192 (1912).
13. Y. C. Wong, *J. Am. Pharm. Assoc. 10,* 431 (1921).
14. *Drug. Circ. 60,* 602 (1916).
15. Fuller, *Story of Drugs,* pp. 98-122.
16. *Drug. Circ. 57,* 142 (1913).
17. *O.P.D. Reptr.* 17 (June 25, 1917); 73 (Nov. 12, 1917).
18. R. C. Stofer, *Pharm. Era 51,* 151 (1918).
19. Tariff Comm., *Tariff Inform. Surv. No. A-9,* 63-79 (1921).
20. Fuller, *op. cit.* p. 103.
21. *Drug Chem. Mkts.* 15 (Jan. 2, 1918).
22. *Ibid.* 11 (Dec. 31, 1919).
23. *Ibid.* 13 (Jan. 4, 1922).

Appendix I

CENSUS OF U. S. CHEMICAL INDUSTRY

(From *Census of Mfrs.*)

Growth of Industry

	1914	*1919*[a]	*1921*[b]
No. establishments	395	781	692
Av. no. wage earners	32,311	71,249	46,306
Capital	$224,346,000	$659,480,000	—
Wages	22,066,000	96,250,000	$ 58,024,000
Cost of materials	89,451,000	280,298,000	190,502,000
Value of products	158,054,000	574,141,000	390,768,000

Value of Chemical Products

Industries			
Chemicals	$158,053,602	$574,141,030	$390,768,434
Sulfuric, nitric, & mixed acids	15,215,474	31,470,480	21,462,920
Subsidiary chemicals	26,926,759	79,656,775	42,142,566
Total	$200,195,835	$685,268,285	$454,373,920
Chemical Groups			
Acids	$32,837,254	$86,194,195	$60,262,890
Nitrogen & fixed nitrogen compounds	9,869,637	26,973,983	21,059,976
Sodium compounds	32,626,335	99,689,828	83,698,199
Potash & potassium compounds	7,905,744	18,407,253	4,934,749
Alums, aluminum, & compounds	([c])	43,433,482	23,243,824
Bleaching compounds	5,302,359	12,392,806	13,900,353
Coal-tar products	13,492,453	133,499,742	75,918,521
Plastics	13,895,784	77,477,041	58,836,711
Compressed & liquefied gases	10,415,325	43,263,918	40,420,835
Chemicals not elsewhere specified			
Inorganic	36,520,217	84,530,613	63,568,998
Organic	16,377,955	72,141,542	44,661,100
Total chemicals, net[d]	$191,895,464	$643,992,900	$443,165,441
Electrochemicals (included above)	$29,661,949	$82,590,005	$57,979,720
Chemical by-products[e]	4,409,620	25,923,661	4,810,803

---

[a] Includes coal-tar products, omitted from 1919 Census; [b] Firms reporting products below $5,000 value excluded; [c] No comparable data; [d] Excluding intergroup duplication; [e] Paints & pigments, druggists' preparations, flavoring extracts, insecticides, soaps & softeners, phosphatic material, etc.

Appendix II

PRICE LIST OF 155 IMPORTANT CHEMICALS AND RELATED PRODUCTS

(From *Drug Chem. Mkts.* and *O.P.D. Reptr.*)

		1914	
		Sept.	Dec.
Acetanilide, U.S.P.	lb.	.20 [d]	.30
Acetone, drums	lb.	.11	.15
Acid, acetic, 28% (bbl.)	cwt.	1.50	1.75
acetylsalicylic (bulk)	lb.	—	—
benzoic	lb.	.25 [d]	.50
boric, cryst. (bbl.)	lb.	.07	.07
citric (makers)	lb.	.58½ [d]	.60
(import., resale)	lb.	.70 [d]	.64
hydrochloric, 22° (carlots, carboys)	cwt.	1.45	1.45
nitric, 42° (carlots, carboys)	cwt.	4.75	4.75
oxalic, cryst.	lb.	.07¼ [b]	.13½
phosphoric, 85%	lb.	.20 [b]	—
picric (kegs)	lb.	.75	.75
salicylic [a]	lb.	.30 [d]	.70
stearic, T.P.	lb.	.12	.12
sulfuric, 66° (tanks, works)	ton	20.00	20.00
tannic, U.S.P. (bulk)	lb.	.75	.75
tech.	lb.	.60	.60
tartaric (import.)	lb.	.30 [d]	.45
Acid phosphate (bulk)	ton	.45 unit	.45 unit
Alcohol, U.S.P., 190°	gal.	2.50 [d]	2.60
Alizarin lake, conc.	lb.	—	—
Alum, ammonia, lump	lb.	.01¾	.01½
potash, lump	lb.	.04	.05
Aluminum, virgin	cwt.	19.00	19.00
hydrate, heavy	lb.	.05	—
light	lb.	.12 [b]	—
sulfate, iron-free	cwt.	1.50	1.50
Ammonia, water, 26° (carlots, drums)	lb.	.04¾	.04¾
Ammonium chloride, white, gran.	lb.	.06½ [b]	.06½
sulfate (double bags, f.a.s.)	cwt.	2.60	2.55
Aniline oil	lb.	.10½	Nom.
salt	lb.	.20	.35
Antimony, crimson	lb.	.30	.30
Antipyrine (bulk)	lb.	—	.22 oz.
Argols	lb.	.02⅝ [b]	.18
Arsenic, white	lb.	.02¾ [b]	.04½
Aspirin (bulk)	lb.	—	—
Barium chloride (dom.)	ton	—	—
(import.)	ton	30.00	60.00
Barytes, prime white, floated (dom.)	ton	19.00	19.00
(import.)	ton	19.00	19.00
Benzaldehyde, U.S.P. [a]	lb.	1.50 [d]	1.00
Benzene, pure (carlots)	gal.	.26	.34
Benzidine base	lb.	—	—
Bismuth subnitrate [a]	lb.	2.50 [d]	2.50
Bleaching powder (spot)	cwt.	3.00	2.00
Blue vitriol	cwt.	4.50	4.35
Borax, cryst., gran., powd. (bbl.)	lb.	.04½	.04¼
Bromine, tech. (bulk)	lb.	.40	.40
Cadmium sulfide, yellow (cwt.)	lb.	—	—
Caffeine	lb.	3.65 [d]	5.00
Calcium chloride (f.s.d., N. Y.)	ton	12.00	12.00
sulfate, U.S.P. [a]	cwt.	2.00 [d]	1.50
Calomel [a]	lb.	.90 [d]	.90
Camphor, Jap., ref.	lb.	.45 [d]	.59
Carbon bisulfide	lb.	.06½	.05½
black	lb.	.04	.04
tetrachloride	lb.	.07 [b]	.12
Chestnut, clarif., 25% tannin	lb.	.05	.05
Chlorine, liq.	lb.	.08	.08
Chlorobenzene	lb.	—	—
Chloroform	lb.	.19 [d]	.30
Cocaine hydrochloride	oz.	2.60 [d]	4.00
Codeine sulfate	oz.	5.50 [d]	6.20
Copper, Prime Lake	cwt.	13.00	13.25
sulfate	cwt.	4.50	4.35
Copperas (works)	cwt.	.65	.65
Coumarin	lb.	3.10 [d]	3.25
Cream of tartar, U.S.P.	lb.	.24 [d]	.30
Cresol, U.S.P.	lb.	—	—
o-Cresol, cryst.	lb.	—	—
Dimethylaniline	lb.	—	—
Dinitrobenzene	lb.	—	—
Diphenylamine	lb.	—	—
Epsom salt, U.S.P. [a]	cwt.	2.00 [d]	1.50
Ether, U.S.P. IX	lb.	.15	.15
Eucalyptol	lb.	.60 [d]	.65
Formaldehyde	lb.	.08½ [d]	.08½
Glycerin, C.P. (drums)	lb.	.19½	.22
Hemlock, 25% tannin	lb.	.02¾	.02¾
Indigo, Bengal	lb.	.67½ [b]	2.00
Madras	lb.	.58 [b]	1.22
[illegible]	lb.	.65	.65

		1914	
		Sept.	Dec.
Lead (open market)	cwt.	3.90	3.80
acetate, white, cryst.	lb.	.09¼	.09¼
carbonate, dry	lb.	.05¼	.05
Lime acetate	cwt.	1.50	1.75
Lithium carbonate	lb.	1.25	1.00
Lithopone	lb.	.03¾	.03¾
Logwood, stick	ton	18.00	18.00
Magnesium carbonate, U.S.P. (kegs)	lb.	.06	.04½
sulfate, tech. (dom.)	cwt.	2.00	1.37
(import.)	cwt.	2.00	1.40
Menthol	lb.	3.00 [d]	2.50
Mercury	flask	33.50	52.00
chloride [a]	lb.	.90 [d]	.90
Morphine sulfate [a]	oz.	4.50 [d]	5.10
Musk ketone	lb.	5.00 [d]	4.50
Naphtha, solvent	gal.	—	—
Naphthalene, flake	lb.	.02⅜ [b]	.04
β-Naphthol	lb.	.08	—
α-Naphthylamine	lb.	—	—
p-Nitroaniline	lb.	.08	—
Nitrotoluene	lb.	—	—
Opium, U.S.P. (cases)	lb.	7.70 [b]	8.90
Para red, tech.	lb.	.07	.07
Para red, toners, conc. (cwt.)	lb.	.60	.80
Phenol	lb.	.08½ [b]	.50
p-Phenylenediamine	lb.	—	—
Phosphorus, yellow	lb.	.45	.35
Phthalic anhydride	lb.	—	—
Potassium bichromate	lb.	.06¾ [b]	.12½
bromide [a]	lb.	.90 [d]	.75
(import., resale) [a]	lb.	.75 [d]	.80
carbonate, 80-85%, calc.	lb.	.28	.13
chlorate (dom.)	lb.	.08 [d]	.17
(import.)	lb.	—	—
hydroxide (dom.)	lb.	—	—
(import.)	lb.	.17	.12
iodide	lb.	2.90 [d]	3.15
permanganate	lb.	.08½ [d]	.15
prussiate, red	lb.	.21 [b]	.45
salts, fertil., *see* Appendix XXV			
Prussian blue (500 lb. lots)	lb.	.26	—
Pyrites, Span., unwashed fines, crude (ex-ship)	unit	.10½	.10½
Quebracho, liq., 35%	lb.	.03½	.03½
solid	lb.	.04¾	.04¾
Quinine sulfate [a]	oz.	.25 [d]	.26
(import., resale) [a]	oz.	.25 [d]	.26
R salt	lb.	—	—
Rochelle salt	lb.	.17 [d]	.21
Rosin, F grade (280 lb.)	bbl.	4.05	3.90
Saccharin	lb.	1.25 [d]	3.50
Sal ammoniac, white, gran.	lb.	.06½ [b]	.06½
Salt cake, ground (bbl.)	ton	11.00 [b]	—
Saltpeter	cwt.	2.25	2.25
Santonin	lb.	30.00 [d]	39.00
Soda ash (makers) light, 48% (works)	cwt.	.57½	.60
(resale) light, 58% (flat)	cwt.	—	—
caustic, *see* Sodium hydroxide			
Sodium benzoate, U.S.P.	lb.	.23½ [d]	.58
bichromate	lb.	.04¾	.04¾
bromide, U.S.P. [a]	lb.	.45 [d]	.55
(import., resale) [a]	lb.	.43 [d]	.55
cyanide, 96-98% (128%)	lb.	.19	.20
hydroxide (makers) 60% (works)	cwt.	1.42½	1.47½
(resale) 76% (flat)	cwt.	—	—
hyposulfite (bbl.)	cwt.	1.30	1.60
nitrate	cwt.	2.25	2.25
nitrite	lb.	.05⅜ [b]	.25
prussiate, yellow	lb.	.18	.18
salicylate [a]	lb.	.27 [d]	.75
silicate, cryst., 40°	lb.	.02	.02
sulfide, 60%	lb.	.02¼	.02¼
Spruce, 25% tannin	lb.	—	—
Strychnine sulfate [a]	oz.	.50 [d]	.50
Sulfur, crude (N. Y.)	ton	20.00	20.00
Superphosphate (bulk)	ton	.45	.45
Terpineol, C.P. [a]	lb.	—	—
Thymol	lb.	2.50 [d]	6.00
Tin, crystals	lb.	.47	.23
Straits (spot)	cwt.	60.00	33.85
p-Toluidine	lb.	—	—
Toluidine, toner	lb.	—	—
Turpentine, spirit	gal.	.45	.47½
Ultramarine blue (bbl.)	lb.	.03½	.03½
Vanillin [a]	oz.	.29 [d]	.35
Vermilion, Chinese	lb.	.90	.90
Eng.	lb.	.55	—
Zinc (open market, spot)	cwt.	5.00	5.70
chloride, fused	lb.	.04½	.04½
oxide, Am.	lb.	.06¾	.06¾

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

PRICE LIST OF 155 IMPORTANT CHEMICALS AND RELATED PRODUCTS (*Cont.*)

		1915			
		Mar.	June	Sept.	Dec.
Acetanilide, U.S.P.	lb.	.75	.80	1.10	1.25
Acetone, drums	lb.	.18	.23	.30	.31
Acid, acetic, 28% (bbl.)	cwt.	1.75	1.75	2.75	3.75
acetylsalicylic (bulk)	lb.	—	—	—	—
benzoic	lb.	1.65	2.10	3.00	3.75
boric, cryst. (bbl.)	lb.	.08	.08	.08¾	.10½
citric (makers)	lb.	.55	.55	.55	.55
(import., resale)	lb.	.55	.90	.55	.55
hydrochloric, 22° (carlots, carboys)	cwt.	1.45	1.45	2.00	2.25
nitric, 42° (carlots, carboys)	cwt.	4.75	4.75	8.00	8.50
oxalic, cryst.	lb.	.16	.21	.40	.50
phosphoric, 85%	lb.	.28[c]	—	—	—
picric (kegs)	lb.	1.15	1.40	1.75	1.50
salicylic[a]	lb.	1.25	2.00	3.00	4.25
stearic, T.P.	lb.	.12	.11	.11	.12½
sulfuric, 66° (tanks, works)	ton	20.00	22.00	25.00	35.00
tannic, U.S.P. (bulk)	lb.	.65	.65	.80	.80
tech.	lb.	.60	.45	.45	.45
tartaric (import.)	lb.	.37	.46	.46	.52
Acid phosphate (bulk)	ton	.45 unit	.45 unit	.45 unit	.80 unit
Alcohol, U.S.P., 190°	gal.	2.50	2.56	2.56	2.64
Alizarin lake, conc.	lb.	—	—	—	—
Alum, ammonia, lump	lb.	.02¾	.03	.03½	.05
potash, lump	lb.	.05	.05	.05	.10
Aluminum, virgin	cwt.	19.00	33.00	42.00	60.00
hydrate, heavy	lb.	.05[c]	—	—	—
light	lb.	.12[c]	—	—	—
sulfate, iron-free	cwt.	1.50	1.50	1.90	1.75
Ammonia, water, 26° (carlots, drums)	lb.	.04¾	.04¾	.04¾	.04¾
Ammonium chloride, white, gran	lb.	.07	.07	.07	.07
sulfate (double bags, f.a.s.)	cwt.	2.90	2.90	3.25	3.25
Aniline oil	lb.	1.00	1.15	1.40	.95
salt	lb.	.70	1.10	1.35	1.35
Antimony, crimson	lb.	.30	.30	.30	.30
Antipyrine (bulk)	lb.	3.00	6.50	16.00	32.00
Argols	lb.	.18[c]	.02¼	.02¼	.02¼
Arsenic, white	lb.	.04	.03⅞	.03⅝	.04
Aspirin (bulk)	lb.	—	—	—	—
Barium chloride (dom.)	ton	—	—	—	—
(import.)	ton	48.00	65.00	90.00	90.00
Barytes, prime white, floated (dom.)	ton	19.00	19.00	19.00	19.00
(import.)	ton	19.00	19.00	19.00	19.00
Benzaldehyde, U.S.P.[a]	lb.	1.25	2.75	4.50	5.50
Benzene, pure (carlots)	gal.	1.10	.75	.90	.80
Benzidine base	lb.	—	—	—	—
Bismuth subnitrate[a]	lb.	2.50	2.50	2.50	2.75
Bleaching powder (spot)	cwt.	2.00	1.40	1.50	6.00
Blue vitriol	cwt.	5.25	7.00	7.25	9.50
Borax, cryst., gran., powd. (bbl.)	lb.	.04¾	.04¾	.05¼	.06¼
Bromine, tech. (bulk)	lb.	.40	.85	1.50	2.50 Nom.
Cadmium sulfide, yellow (cwt.)	lb.	—	—	—	—
Caffeine	lb.	3.70	4.30	9.50	11.00
Calcium chloride (f.s.d., N. Y.)	ton	12.00	12.00	12.00	12.00
sulfate, U.S.P.[a]	cwt.	1.50	1.75	4.00	3.75
Calomel[a]	lb.	.90	1.14	1.43	1.61
Camphor, Jap., ref.	lb.	.41½	.43½	.43	.43
Carbon bisulfide	lb.	.06½	.06½	.07	.06½
black	lb.	.04	.04	.05½	.05½
tetrachloride	lb.	.13	.15	.16½	.15
Chestnut, clarif., 25% tannin	lb.	.05	.06	.06	.05
Chlorine, liq.	lb.	.08	.10	.12	.15
Chlorobenzene	lb.	—	—	—	—
Chloroform	lb.	.28	.28	.35	.50
Cocaine hydrochloride	oz.	3.50	3.50	3.50	3.50
Codeine sulfate	oz.	6.20	6.20	6.20	6.75
Copper, Prime Lake	cwt.	14.75	20.25	17.75	19.75
sulfate	cwt.	5.25	7.00	7.25	9.50
Copperas (works)	cwt.	.65	.65	.55	.55
Coumarin	lb.	3.40	6.00	7.00	7.00
Cream of tartar, U.S.P.	lb.	.28	.32	.34	.36
Cresol, U.S.P.	lb.	—	—	—	—
o-Cresol, cryst.	lb.	—	—	—	—
Dimethylaniline	lb.	—	—	—	1.25
Dinitrobenzene	lb.	—	—	—	—
Diphenylamine	lb.	—	—	—	—
Epsom salt, U.S.P.[a]	cwt.	1.50	1.75	4.00	3.75
Ether, U.S.P. IX	lb.	.15	.15	.15	.15
Eucalyptol	lb.	.65	.65	.65	.65
Formaldehyde	lb.	.08½	.09	.09½	.09½
Glycerin, C.P. (drums)	lb.	.21	.21	.24	.60
Hemlock, 25% tannin	lb.	.02¾	.02¾	.04	.05½
Indigo, Bengal	lb.	2.00	3.00	3.00	3.00
Madras	lb.	1.22	.93	.92	.92
synth., 20% paste	lb.	.65	.65	.65	1.30
Iodine, resublimed	lb.	3.75	3.75	4.25	4.25

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

		1915			
		Mar.	June	Sept.	Dec.
Lead (open market)	cwt.	3.90	5.75	4.90	5.25
acetate, white, cryst.	lb.	.09½	.09½	.11⅝	.11⅝
carbonate, dry	lb.	.05	.05	.06¼	.06¼
Lime acetate	cwt.	1.75	2.50	3.50	3.50
Lithium carbonate	lb.	1.00	1.00	—	—
Lithopone	lb.	.04¼	.05	.06	.06¾
Logwood, stick	ton	18.00	24.00	24.00	24.00
Magnesium carbonate, U.S.P. (kegs)	lb.	.04¼	.04¼	.04¼	.05½
sulfate, tech. (dom.)	cwt.	1.50	1.75	4.00	3.75
(import.)	cwt.	1.50	1.75	—	—
Menthol	lb.	3.00	2.75	2.60	3.15
Mercury	flask	75.00	80.00	89.00	125.00
chloride [a]	lb.	.90	1.14	1.43	1.61
Morphine sulfate [a]	oz.	5.10	5.00	5.00	5.35
Musk ketone	lb.	4.50	8.00	8.50	8.50
Naphtha, solvent	gal.	—	—	—	—
Naphthalene, flake	lb.	.04¾	.15	.16	.13
β-Naphthol	lb.	—	—	—	1.50
α-Naphthylamine	lb.	—	—	—	—
p-Nitroaniline	lb.	—	—	—	—
Nitrotoluene	lb.	—	—	—	—
Opium, U.S.P. (cases)	lb.	7.50	7.00	7.15	11.00
Para red, tech.	lb.	.07	.07	.16	.16
Para red, toners, conc. (cwt.)	lb.	.80	.80	Nom.	Nom.
Phenol	lb.	1.20	1.50	1.40	1.35
p-Phenylenediamine	lb.	—	—	—	—
Phosphorus, yellow	lb.	.35	.35	.35	.35
Phthalic anhydride	lb.	—	—	—	—
Potassium bichromate	lb.	.12½	.15	.20½	.35
bromide [a]	lb.	.70	1.10	1.25	2.50
(import., resale) [a]	lb.	.80	1.10	1.50	3.50
carbonate, 80-85%, calc.	lb.	.15	.18	.30	.35
chlorate (dom.)	lb.	.45	.32	.29	.47
(import.)	lb.	—	—	—	—
hydroxide (dom.)	lb.	—	—	—	—
(import.)	lb.	.08	.23	.40	.60
iodide	lb.	3.15	3.15	3.70	3.70
permanganate	lb.	.30	.70	1.10	1.40
prussiate, red	lb.	.55	1.00	2.25	6.00
salts, fertil., *see* Appendix XXV					
Prussian blue (500 lb. lots)	lb.	.46	.80	1.10	1.50
Pyrites, Span., unwashed fines, crude (ex-ship)	unit	.10½	.10½	.10½	.14½
Quebracho, liq., 35%	lb.	.03½	.03½	.06	.06
solid	lb.	.04¾	.04¾	.10	.12
Quinine sulfate [a]	oz.	.26	.28	.33	.75
(import., resale) [a]	oz.	.25½	.28	.35	.70
R salt	lb.	—	—	—	—
Rochelle salt	lb.	.19	.23½	.26½	.28½
Rosin, F grade (280 lb.)	bbl.	3.50	3.40	3.40	6.00
Saccharin	lb.	2.00	2.85	7.50	12.00
Sal ammoniac, white, gran	lb.	.07	.07	.07	.07
Salt cake, ground (bbl.)	ton	11.00[c]	—	—	—
Saltpeter	cwt.	1.90	1.90	2.50	3.25
Santonin	lb.	41.00	47.00	40.00	38.00
Soda ash (makers) light, 48% (works)	cwt.	.60	.60	.60	.75
(resale) light, 58% (flat)	cwt.	—	—	—	—
caustic, *see* Sodium hydroxide					
Sodium benzoate, U.S.P.	lb.	1.60	1.95	3.00	3.75
bichromate	lb.	.04¼	.05¾	.13	.21
bromide, U.S.P. [a]	lb.	.55	.90	1.25	3.00
(import., resale) [a]	lb.	.55	.90	1.50	3.00
cyanide, 96-98% (128%)	lb.	.22	.22	.28	.28
hydroxide (makers) 60% (works)	cwt.	1.47½	1.85	4.00	4.00
(resale) 76% (flat)	cwt.	—	—	6.35	6.35
hyposulfite (bbl.)	cwt.	1.40	1.40	1.60	1.60
nitrate	cwt.	1.90	1.90	2.50	3.25
nitrite	lb.	.08¼	.07¼	.18	.18
prussiate, yellow	lb.	.11½	.11½	.42	.42
salicylate [a]	lb.	1.45	2.25	3.00	4.25
silicate, cryst., 40°	lb.	.02	.02	.02	.02
sulfide, 60%	lb.	.02¾	.02¾	.03	.03
Spruce, 25% tannin	lb.	—	—	—	—
Strychnine sulfate [a]	oz.	.50	.60	.60	.70
Sulfur, crude (N. Y.)	ton	20.00	20.00	25.00	25.00
Superphosphate (bulk)	ton	.45	.45	.45	.80
Terpineol, C.P. [a]	lb.	—	—	—	—
Thymol	lb.	6.50	8.50	11.00	11.50
Tin, crystals	lb.	.23	.23	.25	.25½
Straits (spot)	cwt.	50.00	39.25	33.75	39.75
p-Toluidine	lb.	—	—	—	—
Toluidine, toner	lb.	—	—	—	—
Turpentine, spirit	gal.	.45	.42	.41	.57
Ultramarine blue (bbl.)	lb.	.03½	.04	.04	.05
Vanillin [a]	oz.	.35	.40	.50	.58
Vermilion, Chinese	lb.	.90	.95	.95	.95
Eng.	lb.	—	1.10	1.40	1.75
Zinc (open market, spot)	cwt.	11.00	22.50	22.50	18.25
chloride, fused	lb.	.05½	.04¼	.08	.10½
oxide, Am.	lb.	.05	.05	.13	.14

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

PRICE LIST OF 155 IMPORTANT CHEMICALS AND RELATED PRODUCTS (*Cont.*)

		1916			
		Mar.	June	Sept.	Dec.
Acetanilide, U.S.P.	lb.	2.00	.80	.58	.50
Acetone, drums	lb.	.45	.40	.30	.31
Acid, acetic, 28% (bbl.)	cwt.	3.50	7.50	6.00	5.00
acetylsalicylic (bulk)	lb.	—	—	—	—
benzoic	lb.	5.00	7.00	10.00	9.00
boric, cryst. (bbl.)	lb.	.11¼	.11¼	.11¼	.11¼
citric (makers)	lb.	.64	.67	.67	.65
(import., resale)	lb.	.70	.82	.63	.67
hydrochloric, 22° (carlots, carboys)	cwt.	3.00	4.50	4.00	2.12½
nitric, 42° (carlots, carboys)	cwt.	8.50	9.62½	9.00	6.50
oxalic, cryst	lb.	.63	.70	.62	.50
phosphoric, 85%	lb.	—	—	—	—
picric (kegs)	lb.	1.00	1.50	1.00	.80
salicylic[a]	lb.	4.00	2.80	1.85	1.20
stearic, T.P.	lb.	.15	.14½	.14	.16
sulfuric, 66° (tanks, works)	ton	50.00	55.00	25.00	25.00
tannic, U.S.P. (bulk)	lb.	.90	1.00	1.00	1.00
tech.	lb.	.55	.60	.60	.65
tartaric (import.)	lb.	.75	.75	.68	.68
Acid phosphate (bulk)	ton	.80 unit	.80 unit	10.50	10.50
Alcohol, U.S.P., 190°	gal.	2.70	2.66	2.66	2.70
Alizarin lake, conc.	lb.	—	—	—	—
Alum, ammonia, lump	lb.	.05	.04	.04	.04
potash, lump	lb.	.09½	.07	.06	.05¼
Aluminum, virgin	cwt.	63.00	61.00	62.00	66.00
hydrate, heavy	lb.	—	—	—	—
light	lb.	—	—	—	.16
sulfate, iron-free	cwt.	4.00	4.00	4.00	4.00
Ammonia, water, 26° (carlots, drums)	lb.	.04¾	.05¾	.05¾	.05¾
Ammonium chloride, white, gran	lb.	.08	.09½	.09½	.16
sulfate (double bags, f.a.s.)	cwt.	3.25	3.75	3.75	4.25
Aniline oil	lb.	.85	.50	.28	.22
salt	lb.	1.15	.70	.45	.29
Antimony, crimson	lb.	Nom.	.48	.48	.48
Antipyrine (bulk)	lb.	60.00	30.00	21.00	18.00
Argols	lb.	.02¼	.02¼	.02¼	.02¼
Arsenic, white	lb.	.06	.06½	.06	.06½
Aspirin (bulk)	lb.	—	—	—	—
Barium chloride (dom.)	ton	—	130.00	105.00	90.00
(import.)	ton	100.00	130.00	—	—
Barytes, prime white, floated (dom.)	ton	35.00	30.00	25.00	25.00
(import.)	ton	24.00	40.00	38.00	38.00
Benzaldehyde, U.S.P.[a]	lb.	5.50	6.50	6.75	5.50
Benzene, pure (carlots)	gal.	.90	.80	.60	.55
Benzidine base	lb.	—	—	2.25	1.90
Bismuth subnitrate[a]	lb.	2.80	3.10	3.10	2.90
Bleaching powder (spot)	cwt.	9.50	7.00	4.00	4.75
Blue vitriol	cwt.	20.00	14.50	9.25	14.00
Borax, cryst., gran., powd. (bbl.)	lb.	.06¾	.07¼	.07¼	.07¼
Bromine, tech. (bulk)	lb.	5.00 Nom.	3.00	1.40	1.40
Cadmium sulfide, yellow (cwt.)	lb.	—	—	—	—
Caffeine	lb.	13.00	18.00	13.00	11.25
Calcium chloride (f.s.d., N. Y.)	ton	12.00	12.00	14.85	14.85
sulfate, U.S.P.[a]	cwt.	3.50	2.75	1.75	1.75
Calomel[a]	lb.	3.43	1.36	1.36	1.43
Camphor, Jap., ref.	lb.	.44	.52	.62½	.80½
Carbon bisulfide	lb.	.09	.08½	.08½	.07
black	lb.	.10	.14	.14	.14
tetrachloride	lb.	.16	.19	.15	.16
Chestnut, clarif., 25% tannin	lb.	.04½	.05	.05	.03
Chlorine, liq.	lb.	.15	.15	.15	.15
Chlorobenzene	lb.	—	—	—	—
Chloroform	lb.	.70	.48	.50	.55
Cocaine hydrochloride	oz.	4.40	4.50	4.25	4.25
Codeine sulfate	oz.	6.75	6.75	6.75	8.25
Copper, Prime Lake	cwt.	27.00	27.00	27.50	33.50
sulfate	cwt.	20.00	14.50	9.25	14.00
Copperas (works)	cwt.	.75	1.25	.90	1.00
Coumarin	lb.	8.00	10.00	9.50	9.50
Cream of tartar, U.S.P.	lb.	.41	.40	.37	.39
Cresol, U.S.P.	lb.	—	—	—	—
o-Cresol, cryst.	lb.	—	—	—	—
Dimethylaniline	lb.	1.10	.75	.70	.57
Dinitrobenzene	lb.	—	—	.45	.40
Diphenylamine	lb.	—	1.50	1.00	.90
Epsom salt, U.S.P.[a]	cwt.	3.50	2.75	1.75	1.75
Ether, U.S.P. IX	lb.	.15	.15	.15	.15
Eucalyptol	lb.	.65	.90	.90	.90
Formaldehyde	lb.	.08	.13	.10½	.11
Glycerin, C.P. (drums)	lb.	.50	.50	.40	.52½
Hemlock, 25% tannin	lb.	.04½	.05	.05½	.04
Indigo, Bengal	lb.	3.50	3.50	3.50	3.50
Madras	lb.	1.50	2.50	2.50	1.03
synth., 20% paste	lb.	1.50	2.00	1.35	1.50
Iodine, resublimed	lb.	4.25	4.25	4.25	4.25

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

		1916			
		Mar.	June	Sept.	Dec.
Lead (open market)	cwt.	6.55	6.40	6.50	7.50
acetate, white, cryst.	lb.	.13⅝	.16	.16	.13
carbonate, dry	lb.	.07	.07	.07	.08¾
Lime acetate	cwt.	3.50	7.00	5.00	3.50
Lithium carbonate	lb.	—	—	1.02	1.02
Lithopone	lb.	.06¾	.06½	.06¼	.06¼
Logwood, stick	ton	35.00	55.00	35.00	25.00
Magnesium carbonate, U.S.P. (kegs)	lb.	.16	.18	.19	.21
sulfate, tech. (dom.)	cwt.	3.50	2.75	1.75	1.62
(import.)	cwt.	—	—	—	—
Menthol	lb.	2.75	3.00	3.00	3.15
Mercury	flask	300.00	122.50	75.00	80.00
chloride [a]	lb.	3.43	1.36	1.36	1.43
Morphine sulfate [a]	oz.	5.35	5.35	5.35	7.00
Musk ketone	lb.	8.50	8.50	11.00	11.50
Naphtha, solvent	gal.	—	—	—	—
Naphthalene, flake	lb.	.15	.10½	.08	.09½
β-Naphthol	lb.	1.50	1.35	1.15	1.15
α-Naphthylamine	lb.	—	1.25	1.25	1.25
p-Nitroaniline	lb.	—	1.60	1.50	1.30
Nitrotoluene	lb.	—	—	—	—
Opium, U.S.P. (cases)	lb.	11.50	11.40	10.75	12.50
Para red, tech	lb.	.18	.50	.40	.40
Para red, toners, conc. (cwt.)	lb.	2.50	2.75	2.50	2.25
Phenol	lb.	1.10	.65	.57½	.55
p-Phenylenediamine	lb.	5.00	5.00	4.50	3.50
Phosphorus, yellow	lb.	.35	.80	.80	.80
Phthalic anhydride	lb.	—	—	—	—
Potassium bichromate	lb.	.65	.58	.40	.40
bromide [a]	lb.	5.50	3.50	1.35	1.35
(import., resale) [a]	lb.	5.20	3.40	1.35	1.35
carbonate, 80-85%, calc.	lb.	.90	.75	.45	.45
chlorate (dom.)	lb.	.65	.58	.47	.66
(import.)	lb.	—	—	—	—
hydroxide (dom.)	lb.	—	.85	.83	.87
(import.)	lb.	.62	—	—	—
iodide	lb.	4.30	4.30	3.75	3.50
permanganate	lb.	1.90	1.60	1.70	2.70
prussiate, red	lb.	5.00	4.50	1.75	2.50
salts, fertil., *see* Appendix XXV					
Prussian blue (500 lb. lots)	lb.	1.50	2.00	1.30	1.00
Pyrites, Span., unwashed fines, crude (ex-ship)	unit	.15	.15	.15	.16
Quebracho, liq., 35%	lb.	.14	.14	.07	.07
solid	lb.	.14	.14	.14	.14
Quinine sulfate [a]	oz.	.75	.75	.65	.55
(import., resale) [a]	oz.	.90	.55	.62	.55
R salt	lb.	—	—	1.90	1.70
Rochelle salt	lb.	.32½	.35	.34	.34
Rosin, F grade (280 lb.)	bbl.	5.40	5.20	6.10	6.80
Saccharin	lb.	13.00	15.00	20.00	20.00
Sal ammoniac, white, gran	lb.	.08	.09½	.09½	.16
Salt cake, ground (bbl.)	ton	—	—	—	—
Saltpeter	cwt.	3.25	3.25	3.10	3.10
Santonin	lb.	37.00	35.00	35.00	35.00
Soda ash (makers) light, 48% (works)	cwt.	1.25	1.25	1.50	—
(resale) light, 58% (flat)	cwt.	3.50	3.25	3.25	3.25
caustic, *see* Sodium hydroxide					
Sodium benzoate, U.S.P.	lb.	4.50	5.50	7.50	8.00
bichromate	lb.	.45	.37	.29	.22
bromide, U.S.P. [a]	lb.	3.50	2.50	.80	.75
(import., resale) [a]	lb.	3.50	2.75	.80	.80
cyanide, 96-98% (128%)	lb.	.40	.40	.40	.87
hydroxide (makers) 60% (works)	cwt.	2.50	2.00	2.25	3.50
(resale) 76% (flat)	cwt.	6.00	6.00	3.75	4.75
hyposulfite (bbl.)	cwt.	2.00	2.70	1.50	1.50
nitrate	cwt.	3.25	3.25	3.10	3.10
nitrite	lb.	.18	.17	.16	.14
prussiate, yellow	lb.	1.25	1.20	.50	.38
salicylate [a]	lb.	4.10	3.00	1.70	1.20
silicate, cryst., 40°	lb.	.02	.02	.02	.02
sulfide, 60%	lb.	.04½	.04½	.03½	.03½
Spruce, 25% tannin	lb.	—	—	—	—
Strychnine sulfate [a]	oz.	.90	.90	.90	.90
Sulfur, crude (N. Y.)	ton	30.00	30.00	30.00	30.00
Superphosphate (bulk)	ton	.80	.80	10.50	10.50
Terpineol, C.P. [a]	lb.	1.05	1.10	1.10	.75
Thymol	lb.	10.50	10.50	10.00	10.00
Tin, crystals	lb.	.29	.35	.29½	.30½
Straits (spot)	cwt.	47.50	39.25	38.50	45.12
p-Toluidine	lb.	—	—	—	—
Toluidine, toner	lb.	—	—	—	—
Turpentine, spirit	gal.	.52½	.43½	.44	.52
Ultramarine blue (bbl.)	lb.	.08	.10	.10	.20
Vanillin [a]	oz.	.60	.59	.58	.57
Vermilion, Chinese	lb.	.95	.95	.95	.95
Eng.	lb.	3.00	1.50	1.50	1.50
Zinc (open market, spot)	cwt.	20.78	9.50	10.00	13.25
chloride, fused	lb.	.13	.17	.13	.13
oxide, Am.	lb.	.16	.18½	.12½	.12½

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

PRICE LIST OF 155 IMPORTANT CHEMICALS AND RELATED PRODUCTS (*Cont.*)

		1917			
		Mar.	June	Sept.	Dec.
Acetanilide, U.S.P.	lb.	.41	.45	.49	.70
Acetone, drums	lb.	.22½	.29½	.35	.35
Acid, acetic, 28% (bbl.)	cwt.	3.75	5.00	5.75	5.50
acetylsalicylic (bulk)	lb.	—	—	—	—
benzoic	lb.	8.25	5.75	2.50	3.00
boric, cryst. (bbl.)	lb.	.12¾	.12¾	.12¾	.13¼
citric (makers)	lb.	.72	.72	.72	.75
(import., resale)	lb.	.72	.72	.72	.75
hydrochloric, 22° (carlots, carboys)	cwt.	2.00	1.75	2.00	2.25
nitric, 42° (carlots, carboys)	cwt.	6.00	6.25	8.50	9.00
oxalic, cryst	lb.	.45	.47	.45	.45½
phosphoric, 85%	lb.	.30	.33½	.36	.35
picric (kegs)	lb.	.75	.75	.75	.85 Nom.
salicylic [a]	lb.	.80	1.20	1.40	1.25
stearic, T.P.	lb.	.17	.25	.25	.26
sulfuric, 66° (tanks, works)	ton	26.00	31.00	35.00	34.00
tannic, U.S.P. (bulk)	lb.	.95	1.15	1.30	1.30
tech.	lb.	.65	.70	.80	.50
tartaric (import.)	lb.	.83	.78	.79	.75
Acid phosphate (bulk)	ton	11.50	14.50	15.00	16.00
Alcohol, U.S.P., 190°	gal.	2.70	3.04	4.30	4.50
Alizarin lake, conc.	lb.	—	—	—	—
Alum, ammonia, lump	lb.	.04	.04¼	.04¼	.04¼
potash, lump	lb.	.05¼	.07½	.07½	.09
Aluminum, virgin	cwt.	59.00	58.00	47.00	37.00
hydrate, heavy	lb.	.08 [c]	—	—	.10
light	lb.	.16	.17	.17	.17
sulfate, iron-free	cwt.	3.00	3.50	3.25	3.25
Ammonia, water, 26° (carlots, drums)	lb.	.05¾	.05¾	.14	.18½
Ammonium chloride, white, gran	lb.	.17	.16½	.14	.15½
sulfate (double bags, f.a.s.)	cwt.	5.00	5.00	5.37½	3.25
Aniline oil	lb.	.28	.30	.26½	.26½
salt	lb.	.29	.34	.33	.32
Antimony, crimson	lb.	.48	.50	.50	.50
Antipyrine (bulk)	lb.	17.50	19.00 Nom.	22.50	22.00
Argols	lb.	.02¼ Nom.	—	—	—
Arsenic, white	lb.	.12	.18	.16	.16
Aspirin (bulk)	lb.	—	—	—	—
Barium chloride (dom.)	ton	90.00	95.00	95.00	95.00
(import.)	ton	—	—	—	—
Barytes, prime white, floated (dom.)	ton	25.00	28.00	28.00	28.00
(import.)	ton	38.00	38.00	38.00	40.00
Benzaldehyde, U.S.P.[a]	lb.	5.05	5.00	5.15	5.15
Benzene, pure (carlots)	gal.	.55	.58	.51	.40
Benzidine base	lb.	1.75	1.85	1.85	1.80
Bismuth subnitrate [a]	lb.	2.85	2.85	2.85	2.85
Bleaching powder (spot)	cwt.	3.50	2.50	2.75	2.00
Blue vitriol	cwt.	10.00	9.50	9.00	9.37½
Borax, cryst., gran., powd. (bbl.)	lb.	.07½	.07½	.07½	.07¾
Bromine, tech. (bulk)	lb.	.50	.55	.60	.60
Cadmium sulfide, yellow (cwt.)	lb.	—	—	—	—
Caffeine	lb.	11.50	13.00	12.50	12.50
Calcium chloride (f.s.d., N. Y.)	ton	28.00	30.00	30.00	30.00
sulfate, U.S.P.[a]	cwt.	3.25	4.25	4.25	3.50
Calomel [a]	lb.	1.67	1.91	1.91	1.91
Camphor, Jap., ref.	lb.	.89½	.86	.85	.76
Carbon bisulfide	lb.	.06½	.06½	.06½	.07
black	lb.	.22	.25	.25	.20
tetrachloride	lb.	.16½	.16	.15½	.15
Chestnut, clarif., 25% tannin	lb.	.03	.03	.03	.03
Chlorine, liq.	lb.	.15	.15	.30	.14
Chlorobenzene	lb.	—	—	—	—
Chloroform	lb.	.57	.58	.60	.68
Cocaine hydrochloride	oz.	5.50	8.50	9.00	9.00
Codeine sulfate	oz.	11.00	11.00	11.25	9.05
Copper, Prime Lake	cwt.	38.00	31.00	27.50	23.50
sulfate	cwt.	10.00	9.50	9.00	9.37½
Copperas (works)	cwt.	1.00	1.00	1.00	1.00
Coumarin	lb.	14.00	20.00	18.00	24.00
Cream of tartar, U.S.P.	lb.	.45	.48½	.49	.58
Cresol, U.S.P.	lb.	—	—	—	—
o-Cresol, cryst.	lb.	—	—	—	—
Dimethylaniline	lb.	.55	.58	.60	.60
Dinitrobenzene	lb.	.45	.33	.33	.33
Diphenylamine	lb.	.85	.90	.90	1.00
Epsom salt, U.S.P.[a]	cwt.	3.25	4.25	4.25	3.50
Ether, U.S.P. IX	lb.	.15	.23	.31	.27
Eucalyptol	lb.	1.20	1.34	1.34	1.34
Formaldehyde	lb.	.13	.17	.16	.18
Glycerin, C.P. (drums)	lb.	.53	.60	.63	.68
Hemlock, 25% tannin	lb.	.04	.04	.04	.04
Indigo, Bengal	lb.	3.75	3.75	3.75	2.50
Madras	lb.	1.40	1.40	1.40	1.10
synth., 20% paste	lb.	—	—	—	—
Iodine, resublimed	lb.	3.50	3.50	3.50	4.25

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

		1917			
		Mar.	June	Sept.	Dec.
Lead (open market)	cwt.	10.25	11.30	10.50	6.50
acetate, white, cryst.	lb.	.13½	.14	.15¾	.17
carbonate, dry	lb.	.08¾	.09¼	.09¼	.09¼
Lime acetate	cwt.	3.50	4.50	6.00	6.00
Lithium carbonate	lb.	1.02	1.25	1.25	1.50
Lithopone	lb.	.06	.06¼	.06¼	.06½
Logwood, stick	ton	30.00	28.00	30.00	36.00
Magnesium carbonate, U.S.P. (kegs)	lb.	.14	.12	.18	.18
sulfate, tech. (dom.)	cwt.	2.25	3.70	3.70	3.25
(import.)	cwt.	—	—	—	—
Menthol	lb.	3.45	3.15	3.05	3.20
Mercury	flask	130.00	90.00	115.00	115.00
chloride [a]	lb.	1.67	1.91	1.91	1.91
Morphine sulfate [a]	oz.	8.80	9.80	10.80	12.80
Musk ketone	lb.	11.50	11.50	12.00	12.00
Naphtha, solvent	gal.	.20	.20	.18	.17
Naphthalene, flake	lb.	.09½	.09¼	.08¾	.09¾
β-Naphthol	lb.	.70	.75	.63	.65
α-Naphthylamine	lb.	1.25	1.15	.80	.70
p-Nitroaniline	lb.	1.25	1.25	1.25	1.10
Nitrotoluene	lb.	—	—	—	—
Opium, U.S.P. (cases)	lb.	20.00	27.00	30.00	30.00 Nom.
Para red, tech.	lb.	.40	.40	.40	.35
Para red, toners, conc. (cwt.)	lb.	2.25	1.75	1.75	1.50
Phenol	lb.	.46	.42	.43	.56
p-Phenylenediamine	lb.	3.50	3.50	3.50	3.50
Phosphorus, yellow	lb.	.80	.80	2.00 Nom.	2.10 Nom.
Phthalic anhydride	lb.	—	6.40	6.40	6.40
Potassium bichromate	lb.	.36	.35½	.39½	.44¾
bromide [a]	lb.	1.35	1.00	1.35	1.45
(import., resale) [a]	lb.	1.00	1.00	1.35	1.45
carbonate, 80-85%, calc.	lb.	.40	.40	.70	.70
chlorate (dom.)	lb.	.62	.52	.54	.47
(import.)	lb.	—	—	—	—
hydroxide (dom.)	lb.	.86	.85	.84	.84
(import.)	lb.	—	—	—	—
iodide	lb.	2.90	2.90	2.90	3.75
permanganate	lb.	3.75	4.00	4.10	3.90
prussiate, red	lb.	2.50	2.50	2.75	2.60
salts, fertil., *see* Appendix XXV					
Prussian blue (500 lb. lots)	lb.	.85	.75	.80	.67
Pyrites, Span., unwashed fines, crude (ex-ship)	unit	.16	.16	.16	.16
Quebracho, liq., 35%	lb.	.07	.07	.07	.07
solid	lb.	.14	.14	.14	.10
Quinine sulfate [a]	oz.	.75	.75	.75	.75
(import., resale) [a]	oz.	.75	.75	.80	.83
R salt	lb.	1.75	1.90	2.00	2.25
Rochelle salt	lb.	.36	.39	.39	.39
Rosin, F grade (280 lb.)	bbl.	6.20	6.20	6.00	7.00
Saccharin	lb.	17.00	32.50	42.00	35.00
Sal ammoniac, white, gran	lb.	.17	.16½	.14	.15½
Salt cake, ground (bbl.)	ton	—	—	—	30.00
Saltpeter	cwt.	3.50	4.00	4.35	4.60
Santonin	lb.	35.00	36.00	36.00	36.00
Soda ash (makers) light, 48% (works)	cwt.	—	—	—	—
(resale) light, 58% (flat)	cwt.	3.00	2.90	4.10	2.75
caustic, *see* Sodium hydroxide					
Sodium benzoate, U.S.P.	lb.	7.50	5.50	2.50	2.85
bichromate	lb.	.18	.15¼	.19½	.16¾
bromide, U.S.P. [a]	lb.	.72	.45	.45	.55
(import., resale) [a]	lb.	.45	.45	.45	.55
cyanide, 96-98% (128%)	lb.	1.20	1.00	1.00	1.00
hydroxide (makers) 60% (works)	cwt.	—	—	—	—
(resale) 76% (flat)	cwt.	4.20	6.50	9.50	7.75
hyposulfite (bbl.)	cwt.	1.60	1.60	1.60	1.60
nitrate	cwt.	3.50	4.00	4.35	4.60
nitrite	lb.	.14	.38	.38	.35
prussiate, yellow	lb.	.30	.30	.30	.34
salicylate [d]	lb.	.85	1.15	1.55	1.20
silicate, cryst., 40°	lb.	.01¾	.02¼	.02¼	—
sulfide, 60%	lb.	.03	.03	.03	.03⅞
Spruce, 25% tannin	lb.	—	—	—	—
Strychnine sulfate [a]	oz.	1.10	1.10	2.05	2.05
Sulfur, crude (N. Y.)	ton	35.00	35.00	45.00	45.00
Superphosphate (bulk)	ton	11.50	14.50	15.00	16.00
Terpineol, C.P. [a]	lb.	.75	.75	.75	.75
Thymol	lb.	14.00	17.00	17.00	16.00
Tin, crystals	lb.	.32	.40	.40	.39
Straits (spot)	cwt.	53.00	62.50	61.87½	80.00
p-Toluidine	lb.	—	.95	.95	.95
Toluidine, toner	lb.	—	—	—	—
Turpentine, spirit	gal.	.50	.43½	.41	.49
Ultramarine blue (bbl.)	lb.	.20	.25	.17	.17
Vanillin [a]	oz.	.55	.65	.65	.85
Vermilion, Chinese	lb.	2.50	2.50	2.50	Nom.
Eng.	lb.	2.25	1.75	1.90	1.65
Zinc (open market, spot)	cwt.	11.00	9.00	8.05	7.87½
chloride, fused	lb.	.13	.14½	.16	.16
oxide, Am.	lb.	.10½	.10½	.10¼	.11

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

PRICE LIST OF 155 IMPORTANT CHEMICALS AND RELATED PRODUCTS (*Cont.*)

		1918			
		Mar.	June	Sept.	Dec.
Acetanilide, U.S.P.	lb.	.80	.75	.68	.60
Acetone, drums	lb.	.35	.25½	.25½	.20
Acid, acetic, 28% (bbl.)	cwt.	6.00	15.75	17.00	4.90
acetylsalicylic (bulk)	lb.	—	2.50	2.50	2.50
benzoic	lb.	5.00	3.50	2.75	2.75
boric, cryst. (bbl.)	lb.	.13¼	.13¼	.13¼	.13¼
citric (makers)	lb.	.75	.82	.82	1.17
(import., resale)	lb.	.75	.86	.82	1.20
hydrochloric, 22° (carlots, carboys)	cwt.	2.75	2.75	2.87½	2.87½
nitric, 42° (carlots, carboys)	cwt.	9.75	9.12½	8.50	8.50
oxalic, cryst	lb.	.45	.42	.40	.39
phosphoric, 85%	lb.	.35 Nom.	.35	.45	.45
picric (kegs)	lb.	.80 Nom.	Nom.	Nom.	.85
salicylic [a]	lb.	1.10	.95	.85	.85
stearic, T.P.	lb.	.27	.26	.25	.26
sulfuric, 66° (tanks, works)	ton	41.00	35.00	28.00	25.00
tannic, U.S.P. (bulk)	lb.	1.30	1.30	1.40	1.40
tech	lb.	.55	.60	.65	.65
tartaric (import.)	lb.	.75	.83	.87½	.85
Acid phosphate (bulk)	ton	18.00	18.00	18.00	17.00
Alcohol, U.S.P., 190°	gal.	4.93	4.93	4.91	4.91
Alizarin lake, conc.	lb.	2.75	Nom.	Nom.	Nom.
Alum, ammonia, lump	lb.	.04¼	.04⅛	.05¼	.07¾
potash, lump	lb.	.09	.08	.12	.11
Aluminum, virgin	cwt.	32.00	33.10	33.20	33.20
hydrate, heavy	lb.	.10	.11	.11	.11
light	lb.	.17	.17	.17	.17
sulfate, iron-free	cwt.	3.50	3.50	3.50	4.25
Ammonia, water, 26° (carlots, drums)	lb.	.24	.27	.16½	.08½
Ammonium chloride, white, gran	lb.	.15	.19	.18	.18
sulfate (double bags, f.a.s.)	cwt.	3.25	3.25	8.00	8.00
Aniline oil	lb.	.25¼	.27¼	.28½	.28
salt	lb.	.32	.33	.43	.40
Antimony, crimson	lb.	.35	.35	.35	.35
Antipyrine (bulk)	lb.	20.00	18.00	19.50	20.00
Argols	lb.	—	—	—	.11
Arsenic, white	lb.	.16	.12	.10	.11
Aspirin (bulk)	lb.	—	2.50	2.50	2.50
Barium chloride (dom.)	ton	70.00	66.00	85.00	75.00
(import.)	ton	—	—	—	—
Barytes, prime white, floated (dom.)	ton	28.00	32.00	33.00	32.00
(import.)	ton	40.00	Nom.	Nom.	Nom.
Benzaldehyde, U.S.P.[a]	lb.	4.50	4.50	5.20	5.20
Benzene, pure (carlots)	gal.	.31	.25½	.25	.20
Benzidine base	lb.	1.75	1.75	1.75	1.70
Bismuth subnitrate [a]	lb.	2.85	3.30	3.30	3.30
Bleaching powder (spot)	cwt.	2.50	2.50	3.75	3.00
Blue vitriol	cwt.	9.00	9.00	9.00	9.25
Borax, cryst., gran., powd. (bbl.)	lb.	.07¾	.07¾	.07¾	.07¾
Bromine, tech. (bulk)	lb.	.75	.75	.75	.55
Cadmium sulfide, yellow (cwt.)	lb.	2.00	2.00	2.00	2.00
Caffeine	lb.	13.00	11.75	10.50	10.00
Calcium chloride (f.s.d., N. Y.)	ton	28.00	24.00	24.00	22.50
sulfate, U.S.P.[a]	cwt.	3.25	3.00	3.25	3.25
Calomel [a]	lb.	1.91	1.91	2.00	2.00
Camphor, Jap., ref.	lb.	.92½	1.10	1.17½	3.50
Carbon bisulfide	lb.	.07½	.08½	.08½	.09
black	lb.	.20	.16	.16	.16
tetrachloride	lb.	.15	.16½	.40	.35
Chestnut, clarif., 25% tannin	lb.	.03	.02½	.02⅞	.03
Chlorine, liq.	lb.	.14½	.15	.15	.12
Chlorobenzene	lb.	.15 [c]	—	—	.21
Chloroform	lb.	.63	.62	.63	.58
Cocaine hydrochloride	oz.	9.00	13.00	11.50	11.00
Codeine sulfate	oz.	8.05	7.30	7.30	8.90
Copper, Prime Lake	cwt.	23.50	26.00	26.00	26.00
sulfate	cwt.	9.00	9.00	9.00	9.25
Copperas (works)	cwt.	1.10	1.25	1.95	2.50
Coumarin	lb.	25.00	30.00	31.00	15.00
Cream of tartar, U.S.P.	lb.	.58	.75	.76	.63
Cresol, U.S.P.	lb.	.17	.18	.18	.18
o-Cresol, cryst.	lb.	.35	.35	.35	.35
Dimethylaniline	lb.	.63¾	.69	.76	.75
Dinitrobenzene	lb.	.34	.34	.35	.40
Diphenylamine	lb.	.90	.90	1.05	1.00
Epsom salt, U.S.P.[a]	cwt.	3.25	3.00	3.25	3.25
Ether, U.S.P. IX	lb.	.27	.27	.27	.28
Eucalyptol	lb.	1.34	1.34	1.35	1.29
Formaldehyde	lb.	.19	.19	.16¼	.16¼
Glycerin, C.P. (drums)	lb.	.66	.62½	.60½	.22
Hemlock, 25% tannin	lb.	.03¼	.03¼	.05½	.05½
Indigo, Bengal	lb.	2.50	2.25	3.00	3.25
Madras	lb.	1.10	.90	.80	.80
synth., 20% paste	lb.	—	—	1.15	1.15
Iodine, resublimed	lb.	4.25	4.25	4.25	4.25

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

		1918			
		Mar.	June	Sept.	Dec.
Lead (open market)	cwt.	7.25	7.00	8.05	6.00
acetate, white, cryst.	lb.	.16	.17⅛	.17¼	.17
carbonate, dry	lb.	.09¼	.09¼	.09¼	.09¼
Lime acetate	cwt.	6.00	6.00	4.00	4.00
Lithium carbonate	lb.	1.50	1.50	1.50	1.50
Lithopone	lb.	.06½	.07	.07½	.07¾
Logwood, stick	ton	36.00	40.00	50.00	45.00
Magnesium carbonate, U.S.P. (kegs)	lb.	.18	.20	.25	.25
sulfate, tech. (dom.)	cwt.	3.25	3.37	3.37	3.37
(import.)	cwt.	—	—	—	—
Menthol	lb.	3.30	3.30	3.60	6.70
Mercury	flask	135.00	125.00	128.00	123.00
chloride [a]	lb.	1.91	1.91	2.00	2.00
Morphine sulfate [a]	oz.	12.80	11.80	11.80	11.80
Musk ketone	lb.	12.00	30.00	30.00	30.00
Naphtha, solvent	gal.	.18	.18	.18	.20
Naphthalene, flake	lb.	.10½	.09¼	.08½	.07¼
β-Naphthol	lb.	.65	.60	.65	.60
α-Naphthylamine	lb.	.62	.60	.61	.55
p-Nitroaniline	lb.	1.05	1.70	1.85	1.40
Nitrotoluene	lb.	.55	.55	.55	.65
Opium, U.S.P. (cases)	lb.	27.00 Nom.	23.00	21.50	22.50
Para red, tech.	lb.	.35	.20	.20	.20
Para red, toners, conc. (cwt.)	lb.	1.50	1.50	1.70	1.70
Phenol	lb.	.53	.46½	.43	.30
p-Phenylenediamine	lb.	3.50	3.50	4.00	3.25
Phosphorus, yellow	lb.	2.10	1.35	1.35	1.35
Phthalic anhydride	lb.	4.60	3.80	4.25	3.25
Potassium bichromate	lb.	.44	.44	.45	.42½
bromide [a]	lb.	1.35	1.35	1.25	.75
(import., resale) [a]	lb.	1.40	1.30	1.25	.65
carbonate, 80-85%, calc.	lb.	.68	.68	.68	.35
chlorate (dom.)	lb.	.40	.28	.32	.34
(import.)	lb.	—	—	—	—
hydroxide (dom.)	lb.	.83½	.82½	.74¾	.67
(import.)	lb.	—	—	—	—
iodide	lb.	3.75	3.75	3.75	3.75
permanganate	lb.	4.00	3.00	1.75	1.60
prussiate, red	lb.	2.60	2.60	2.50	2.00
salts, fertil., *see* Appendix XXV					
Prussian blue (500 lb. lots)	lb.	.70	1.10	1.35	Nom.
Pyrites, Span., unwashed fines, crude (ex-ship)	unit	.17	.17	.17	.17
Quebracho, liq., 35%	lb.	.07	.06½	Nom.	Nom.
solid	lb.	.08	.04½	Nom.	.09½
Quinine sulfate [a]	oz.	.75	.90	.90	.90
(import., resale) [a]	oz.	.86	1.20	.92	1.05
R salt	lb.	2.25	2.05	2.05	2.00
Rochelle salt	lb.	.39	.43	.46½	.46
Rosin, F grade (280 lb.)	bbl.	6.70	8.30	12.00	15.80
Saccharin	lb.	19.00	22.00	35.00	7.00
Sal ammoniac, white, gran	lb.	.15	.19	.18	.18
Salt cake, ground (bbl.)	ton	30.00	30.00	35.00	35.00
Saltpeter	cwt.	4.40	5.50	4.10	4.32
Santonin	lb.	37.00	45.00	45.00	47.50
Soda ash (makers) light, 48% (works)	cwt.	—	—	—	—
(resale) light, 58% (flat)	cwt.	2.75	2.15	3.00	2.65
caustic, *see* Sodium hydroxide					
Sodium benzoate, U.S.P.	lb.	4.75	3.40	2.75	2.50
bichromate	lb.	.25	.24	.24¼	.17½
bromide, U.S.P. [a]	lb.	.65	.65	.65	.60
(import., resale) [a]	lb.	.63	.65	.70	.65
cyanide, 96-98% (128%)	lb.	.38	.38	.38	.30
hydroxide (makers) 60% (works)	cwt.	—	—	—	—
(resale) 76% (flat)	cwt.	4.75	4.40	4.30	4.15
hyposulfite (bbl.)	cwt.	2.25	2.50	2.75	2.65
nitrate	cwt.	4.40	5.50	4.10	4.32
nitrite	lb.	.33¼	.41½	.26	.26
prussiate, yellow	lb.	.37¼	.74	.52	.32
salicylate [a]	lb.	1.10	.90	.90	.85
silicate, cryst., 40°	lb.	.02	.02¼	.02	.01¾
sulfide, 60%	lb.	.03⅞	.04¼	.08½	.09
Spruce, 25% tannin	lb.	.00¾	.00⅞	.01	.01
Strychnine sulfate [a]	oz.	2.05	1.20	1.40	1.40
Sulfur, crude (N. Y.)	ton	45.00	45.00	Nom.	Nom.
Superphosphate (bulk)	ton	18.00	18.00	18.00	17.00
Terpineol, C.P. [a]	lb.	.75	1.25	1.25	1.25
Thymol	lb.	15.00	14.00	13.25	13.50
Tin, crystals	lb.	.30	Nom.	Nom.	Nom.
Straits (spot)	cwt.	84.00	94.00	90.00	72.50
p-Toluidine	lb.	.95	.95	.85	.85
Toluidine, toner	lb.	4.50	4.50	4.50	5.50
Turpentine, spirit	gal.	.43	.50	.65	.75
Ultramarine blue (bbl.)	lb.	.17	.17	.14	.14
Vanillin [a]	oz.	.82	.80	.80	.87
Vermilion, Chinese	lb.	Nom.	Nom.	Nom.	Nom.
Eng.	lb.	1.85	2.00	2.00	2.00
Zinc (open market, spot)	cwt.	7.20	7.40	9.25	8.45
chloride, fused	lb.	.16	.15½	.15½	.15½
oxide, Am.	lb.	.11¼	.12½	.13¾	.13¾

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

PRICE LIST OF 155 IMPORTANT CHEMICALS AND RELATED PRODUCTS (*Cont.*)

		1919			
		Mar.	June	Sept.	Dec.
Acetanilide, U.S.P.	lb.	.44	.37	.38	.54
Acetone, drums	lb.	.15½	.15	.15	.15
Acid, acetic, 28% (bbl.)	cwt.	4.00	2.75	3.75	3.75
acetylsalicylic (bulk)	lb.	1.30	.75	.80	.95
benzoic	lb.	1.50	.70	.85	.80
boric, cryst. (bbl.)	lb.	.13¼	.13¼	.13¼	.14¼
citric (makers)	lb.	1.25½	.98	.98	.90
(import., resale)	lb.	1.25	.95	.87	.83
hydrochloric, 22° (carlots, carboys)	cwt.	1.75	1.50	2.25	2.00
nitric, 42° (carlots, carboys)	cwt.	8.50	7.00	7.50	7.50
oxalic, cryst	lb.	.33	.25	.23	.25
phosphoric, 85%	lb.	.36	.34	.34	.34
picric (kegs)	lb.	.50	.50	.25	.25
salicylic[a]	lb.	.40	.22½	.45	.50
stearic, T.P.	lb.	.20	.27	.30	.30
sulfuric, 66° (tanks, works)	ton	22.00	16.00	17.00	21.00
tannic, U.S.P. (bulk)	lb.	1.40	1.30	1.35	1.35
tech.	lb.	.65	.45	.60	.65
tartaric (import.)	lb.	.84	.85	.85	.70
Acid phosphate (bulk)	ton	16.50	15.50	18.00	19.00
Alcohol, U.S.P., 190°	gal.	4.90	4.90	4.90	4.70
Alizarin lake, conc.	lb.	Nom.	2.50	2.50	3.75
Alum, ammonia, lump	lb.	.04½	.04½	.04	.04
potash, lump	lb.	.09	.08	.08	.07¾
Aluminum, virgin	cwt.	33.20	33.00	32.00	31.50
hydrate, heavy	lb.	.09	.08½	.08	.08
light	lb.	.18	.17	.15	.15
sulfate, iron-free	cwt.	4.00	3.00	2.50	2.75
Ammonia, water, 26° (carlots, drums)	lb.	.08½	.06½	.07	.09
Ammonium chloride, white, gran.	lb.	.13	.12	.12	.13½
sulfate (double bags, f.a.s.)	cwt.	8.00	4.50	4.75	7.00
Aniline oil	lb.	.24	.22	.30	.33
salt	lb.	.31	.28	.30	.37
Antimony, crimson	lb.	.35	.35	.35	.35
Antipyrine (bulk)	lb.	20.00	13.00	6.00	5.60
Argols	lb.	.11	.08	.10	.10
Arsenic, white	lb.	.10	.08	.10	.10
Aspirin (bulk)	lb.	1.30	.75	.80	.95
Barium chloride (dom.)	ton	25.00	70.00	75.00	85.00
(import.)	ton	—	—	—	80.00
Barytes, prime white, floated (dom.)	ton	30.00	30.00	30.00	30.00
(import.)	ton	Nom.	Nom.	Nom.	Nom.
Benzaldehyde, U.S.P.[a]	lb.	2.00	1.50	1.25	1.00
Benzene, pure (carlots)	gal.	.22	.24	.25	.25
Benzidine base	lb.	1.35	.90	1.00	1.25
Bismuth subnitrate[a]	lb.	3.30	3.20	3.00	3.00
Bleaching powder (spot)	cwt.	1.75	1.25	2.25	2.50
Blue vitriol	cwt.	7.75	7.00	8.85	8.12½
Borax, cryst., gran., powd. (bbl.)	lb.	.07¾	.07¾	.07¾	.08¼
Bromine, tech. (bulk)	lb.	.55	.55	.55	.75
Cadmium sulfide, yellow (cwt.)	lb.	2.00	2.00	1.50	1.50
Caffeine	lb.	8.50	6.75	7.00	7.00
Calcium chloride (f.s.d., N. Y.)	ton	22.50	19.00	18.00	20.00
sulfate, U.S.P.[a]	cwt.	2.75	2.25	2.00	2.50
Calomel[a]	lb.	1.51	1.59	1.76	1.59
Camphor, Jap., ref.	lb.	2.55	2.50	2.95	3.55
Carbon bisulfide	lb.	.09	.06	.06	.06
black	lb.	.14	.12	.12	.12
tetrachloride	lb.	.14¼	.13	.10½	.11
Chestnut, clarif., 25% tannin	lb.	.03⅛	.03⅛	.03¼	.03¼
Chlorine, liq.	lb.	.08	.06	.07½	.09½
Chlorobenzene	lb.	.13	.10	.10	.10
Chloroform	lb.	.40	.30	.30	.30
Cocaine hydrochloride	oz.	9.50	9.50	9.50	9.50
Codeine sulfate	oz.	8.90	8.90	8.90	9.10
Copper, Prime Lake	cwt.	15.50	20.00	23.12½	19.00
sulfate	cwt.	7.75	7.00	8.85	8.12½
Copperas (works)	cwt.	1.85	1.15	1.05	1.20
Coumarin	lb.	10.00	6.75	6.75	8.25
Cream of tartar, U.S.P.	lb.	.55	.52	.53	.55
Cresol, U.S.P.	lb.	.18	.15	.14¾	.14½
o-Cresol, cryst.	lb.	.30	.20	.20	.18
Dimethylaniline	lb.	.57	.50	.55	.90
Dinitrobenzene	lb.	.34	.32	.23	.26
Diphenylamine	lb.	.75	.70	.53	.65
Epsom salt, U.S.P.[a]	cwt.	2.75	2.25	2.00	2.50
Ether, U.S.P. IX	lb.	.23	.19	.19 conc. cwt.	.17 conc. cwt.
Eucalyptol	lb.	1.29	1.15	1.10	1.55
Formaldehyde	lb.	.22	.20	.19	.33
Glycerin, C.P. (drums)	lb.	.18	.21	.21	.21
Hemlock, 25% tannin	lb.	.05½	.05½	.05½	.05½
Indigo, Bengal	lb.	3.25	2.75	2.25	2.25
Madras	lb.	.80	.95	.95	.95
synth., 20% paste	lb.	.75	.70	.85	.85
Iodine, resublimed	lb.	4.25	4.25	4.50	4.10

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

		1919			
		Mar.	June	Sept.	Dec.
Lead (open market)	cwt.	5.00	5.40	6.75	8.75
acetate, white, cryst.	lb.	.14	.14	.14	.14
carbonate, dry	lb.	.09¼	.09¼	.09¼	.09¼
Lime acetate	cwt.	2.00	2.00	2.00	2.00
Lithium carbonate	lb.	1.50	1.50	1.50	1.50
Lithopone	lb.	.06½	.06½	.07	.07
Logwood, stick	ton	36.00	36.00	25.00	36.00
Magnesium carbonate, U.S.P. (kegs)	lb.	.25	.21	.21	.21
sulfate, tech. (dom.)	cwt.	2.75	2.25	2.00	2.20
(import.)	cwt.	—	—	—	—
Menthol	lb.	5.85	5.90	7.85	13.25
Mercury	flask	85.00	92.00	95.00	90.00
chloride[a]	lb.	1.51	1.59	1.76	1.59
Morphine sulfate[a]	oz.	11.80	10.80	9.80	8.80
Musk ketone	lb.	30.00	30.00	30.00	35.00
Naphtha, solvent	gal.	.20	.20	.25	.32
Naphthalene, flake	lb.	.08½	.06	.06	.07
β-Naphthol	lb.	.55	.40	.45	.55
α-Naphthylamine	lb.	.45	.35	.32	.33
p-Nitroaniline	lb.	1.35	.95	.95	1.15
Nitrotoluene	lb.	.40	.40	.40	.18
Opium, U.S.P. (cases)	lb.	22.50	8.00	7.00	6.75
Para red, tech.	lb.	.20	.20	.20	.20
Para red, toners, conc. (cwt.)	lb.	1.60	1.60	1.60	1.65
Phenol	lb.	.08	.11½	.12	.19
p-Phenylenediamine	lb.	3.25	2 75	2.75	2.25
Phosphorus, yellow	lb.	1.35	.35	.35	.35
Phthalic anhydride	lb.	2.25	1.80	.80	.60
Potassium bichromate	lb.	.36½	.28	.25	.28
bromide[a]	lb.	.55	.55	.50	.75
(import., resale)[a]	lb.	.49	.55	.50	.75
carbonate, 80-85%, calc.	lb.	.25	.14	.16¾	.25
chlorate (dom.)	lb.	.30	.25	.19	.18
(import.)	lb.	—	.22	.19	.16½
hydroxide (dom.)	lb.	.63	.35	.28	.28
(import.)	lb.	—	—	—	.32
iodide	lb.	3.75	3.25	3.25	3.50
permanganate	lb.	.90	.55	.50	.58
prussiate, red	lb.	1.30	.80	1.05	1.00
salts, fertil., *see* Appendix XXV					
Prussian blue (500 lb. lots)	lb.	.80	.60	.65	.75
Pyrites, Span., unwashed fines, crude (ex-ship)	unit	.17	.15	.16½	.16½
Quebracho, liq., 35%	lb.	.06½	.06	.06	.05½
solid	lb.	.09½	.10½	.11	.11½
Quinine sulfate[a]	oz.	.90	.80	.80	.80
(import., resale)[a]	oz.	1.02	.90	.85	1.40
R salt	lb.	1.75	1.50	1.50	1.75
Rochelle salt	lb.	.46	.43	.43	.39
Rosin, F grade (280 lb.)	bbl.	14.00	13.00	17.00	19.00
Saccharin	lb.	4.75	4.00	3.50	3.50
Sal ammoniac, white, gran	lb.	.13	.12	.12	.13½
Salt cake, ground (bbl.)	ton	18.00	17.00	17.00	17.00
Saltpeter	cwt.	4.32	4.00	2.95	2.95
Santonin	lb.	47.50	49.00	110.00	80.00
Soda ash (makers) light, 48% (works)	cwt.	—	—	1.75	1.75
(resale) light, 58% (flat)	cwt.	1.50	1.60	1.90	1.90
caustic, *see* Sodium hydroxide					
Sodium benzoate, U.S.P.	lb.	1.40	.70	.85	.75
bichromate	lb.	.13	.08	.14	.15¾
bromide, U.S.P.[a]	lb.	.50	.50	.50	.59
(import., resale)[a]	lb.	.49	.49	.49	.59
cyanide, 96-98% (128%)	lb.	.30	.26	.30	.30
hydroxide (makers) 60% (works)	cwt.	—	—	—	—
(resale) 76% (flat)	cwt.	3.00	2.50	3.25	4.00
hyposulfite (bbl.)	cwt.	2.60	3.60	3.60	3.60
nitrate	cwt.	4.32	4.00	2.95	2.95
nitrite	lb.	.14	.14	.08½	.14
prussiate, yellow	lb.	.26	.17	.18	.25
salicylate[a]	lb.	.50	.35	.50	.60
silicate, cryst., 40°	lb.	.02	.02	.01½	.01⅛
sulfide, 60%	lb.	.06	.05	.04½	.04½
Spruce, 25% tannin	lb.	.01	.01	.01	.01
Strychnine sulfate[a]	oz.	1.40	1.40	1.40	1.40
Sulfur, crude (N. Y.)	ton	65.00	35.00	25.00	25.00
Superphosphate (bulk)	ton	16.50	15.50	18.00	19.00
Terpineol, C.P.[a]	lb.	1.25	1.25	1.25	1.25
Thymol	lb.	10.00	7.00	6.00	10.00
Tin, crystals	lb.	Nom.	Nom.	.48	.43
Straits (spot)	cwt.	72.50	70.50	56.00	52.75
p-Toluidine	lb.	.85	.85	.62½	.62½
Toluidine, toner	lb.	3.25	4.00	3.75	3.25
Turpentine, spirit	gal.	.71½	.99	1.85	1.75
Ultramarine blue (bbl.)	lb.	.12	.12	.12	.35
Vanillin[a]	oz.	.70	.65	.75	.95
Vermilion, Chinese	lb.	Nom.	—	—	—
Eng.	lb.	1.40	1.50	1.40	1.40
Zinc (open market, spot)	cwt.	6.50	7.20	8.00	9.50
chloride, fused	lb.	.14	.08	.09	.09
oxide, Am.	lb.	.12	.12	.12	.12

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.Sept. price.

Price List of 155 Important Chemicals and Related Products (*Cont.*)

		1920			
		Mar.	June	Sept.	Dec.
Acetanilide, U.S.P.	lb.	.60	.75	.60	.40
Acetone, drums	lb.	.15	.22	.22	.13½
Acid, acetic, 28% (bbl.)	cwt.	2.50	4.00	4.00	3.50
acetylsalicylic (bulk)	lb.	.95	.85	.85	.70
benzoic	lb.	.85	.85	.80	.70
boric, cryst. (bbl.)	lb.	.14¼	.14¼	.14¼	.14¼
citric (makers)	lb.	.84	.84	.84	.55
(import., resale)	lb.	1.05	1.06	.72	.45
hydrochloric, 22° (carlots, carboys)	cwt.	2.00	3.50	2.75	2.10
nitric, 42° (carlots, carboys)	cwt.	8.00	8.00	8.50	7.75
oxalic, cryst	lb.	.44	.58	.52	.17
phosphoric, 85%	lb.	.33	.33	.33	.30
picric (kegs)	lb.	.23	.30	.30	.30
salicylic[a]	lb.	.55	.55	.55	.45
stearic, T.P.	lb.	.33	.29	.25½	.16½
sulfuric, 66° (tanks, works)	ton	22.00	21.00	22.00	20.00
tannic, U.S.P. (bulk)	lb.	1.40	1.60	1.60	1.20
tech.	lb.	.65	.80	.75	.45
tartaric (import.)	lb.	.69	.84	.67	.45
Acid phosphate (bulk)	ton	19.00	18.50	21.00	18.00
Alcohol, U.S.P., 190°	gal.	6.50	6.50	6.50	5.50
Alizarin lake, conc.	lb.	3.75	3.75	3.35	1.90
Alum, ammonia, lump	lb.	.04	.05	.04¾	.04¾
potash, lump	lb.	.07¾	.07¾	.07¾	.06
Aluminum, virgin	cwt.	32.00	32.00	32.00	27.00
hydrate, heavy	lb.	.09	.08½	.10	.08½
light	lb.	.18	.22	.25	.23
sulfate, iron-free	cwt.	2.50	4.00	5.50	4.50
Ammonia, water, 26° (carlots, drums)	lb.	.08½	.08¾	.09	.09
Ammonium chloride, white, gran	lb.	.15	.15	.15	.11½
sulfate (double bags, f.a.s.)	cwt.	7.40	7.00	5.85	4.00
Aniline oil	lb.	.34	.35	.27½	.22
salt	lb.	.42	.37	.34	.28
Antimony, crimson	lb.	.45	.45	.45	.45
Antipyrine (bulk)	lb.	6.75	5.75	3.75	2.50
Argols	lb.	.10	.10½	.10½	.10
Arsenic, white	lb.	.12½	.14½	.14	.11½
Aspirin (bulk)	lb.	.95	.85	.85	.70
Barium chloride (dom.)	ton	160.00	160.00	140.00	100.00
(import.)	ton	—	—	140.00	85.00
Barytes, prime white, floated (dom.)	ton	34.00	Nom.	35.00	32.00
(import.)	ton	Nom.	Nom.	Nom.	Nom.
Benzaldehyde, U.S.P.[a]	lb.	1.00	1.00	1.00	1.00
Benzene, pure (carlots)	gal.	.27	.27	.30	.30
Benzidine base	lb.	1.40	1.35	1.25	1.00
Bismuth subnitrate[a]	lb.	2.65	2.85	2.85	2.60
Bleaching powder (spot)	cwt.	2.50	5.50	7.00	4.00
Blue vitriol	cwt.	8.25	8.25	8.25	6.00
Borax, cryst., gran., powd. (bbl.)	lb.	.08½	.08½	.08½	.07¼
Bromine, tech. (bulk)	lb.	.85	.85	.95	.53
Cadmium sulfide, yellow (cwt.)	lb.	1.75	1.50	1.75	1.40
Caffeine	lb.	7.25	7.75	7.75	6.75
Calcium chloride (f.s.d., N. Y.)	ton	20.00	27.50	33.00	33.75
sulfate, U.S.P.[a]	cwt.	2.00	3.50	3.75	3.00
Calomel[a]	lb.	1.52	1.64	1.52	1.10
Camphor, Jap., ref.	lb.	2.75	1.80	1.30	.95
Carbon bisulfide	lb.	.06½	.08	.08	.08
black	lb.	.12	.15	.12	.10
tetrachloride	lb.	.10½	.14	.13	.12
Chestnut, clarif., 25% tannin	lb.	.03¼	.03¼	.03¼	.02½
Chlorine, liq.	lb.	.09½	.07½	.07½	.09
Chlorobenzene	lb.	.10¼	.17	.14	.14
Chloroform	lb.	.30	.40	.40	.40
Cocaine hydrochloride	oz.	10.50	10.50	10.50	10.50
Codeine sulfate	oz.	9.10	9.10	9.10	7.50
Copper, Prime Lake	cwt.	19.50	18.75	19.00	14.00
sulfate	cwt.	8.25	8.25	8.25	6.00
Copperas (works)	cwt.	1.30	1.75	2.20	1.50
Coumarin	lb.	6.50	6.50	6.50	6.00
Cream of tartar, U.S.P.	lb.	.53	.53	.52	.40
Cresol, U.S.P.	lb.	.15¾	.17	.18	.16
o-Cresol, cryst.	lb.	.20	.23	.23	.18
Dimethylaniline	lb.	1.30	1.25	.80	.75
Dinitrobenzene	lb.	.43	.35	.32	.29
Diphenylamine	lb.	.80	.85	.80	.70
Epsom salt, U.S.P.[a]	cwt.	2.00	3.50	3.75	3.00
Ether, U.S.P. IX	lb.	.19 conc. cwt.	.21 conc. cwt	.23 conc. cwt.	.23 conc. cwt.
Eucalyptol	lb.	1.50	1.35	1.10	1.10
Formaldehyde	lb.	.38	.56	.44	.17
Glycerin, C.P. (drums)	lb.	.23½	.27	.28	.21
Hemlock, 25% tannin	lb.	.05	.05	.05	.04
Indigo, Bengal	lb.	2.25	2.00	2.00	2.00
Madras	lb.	.95	.90	.90	.85
synth., 20% paste	lb.	.75	.85	.85	.85
Iodine, resublimed	lb.	4.10	4.35	4.35	4.00

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

		1920			
		Mar.	June	Sept.	Dec.
Lead (open market)	cwt.	9.20	8.50	8.75	5.12½
acetate, white, cryst.	lb.	.14	.15	.16	.12½
carbonate, dry	lb.	.09¼	.09¼	.10½	.10½
Lime acetate	cwt.	2.00	3.50	3.50	2.50
Lithium carbonate	lb.	1.50	1.50	1.50	1.50
Lithopone	lb.	.07¼	.08	.08½	.07¾
Logwood, stick	ton	Nom.	47.00	47.00	30.00
Magnesium carbonate, U.S.P. (kegs)	lb.	.17	.17	.18	.15
sulfate, tech. (dom.)	cwt.	2.00	3.50	3.35	3.00
(import.)	cwt.	—	—	—	1.75
Menthol	lb.	13.50	9.00	7.35	4.00
Mercury	flask	85.00	80.00	75.00	53.00
chloride [a]	lb.	1.52	1.64	1.52	1.10
Morphine sulfate [a]	oz.	8.80	8.80	7.80	5.80
Musk ketone	lb.	45.00	50.00	45.00	35.00
Naphtha, solvent	gal.	.22	.25	.30	.28
Naphthalene, flake	lb.	.08½	.16	.16½	.09
β-Naphthol	lb.	.55	.85	.80	.42
α-Naphthylamine	lb.	.40	.60	.50	.40
p-Nitroaniline	lb.	1.35	1.65	1.10	1.05
Nitrotoluene	lb.	.16	—	—	—
Opium, U.S.P. (cases)	lb.	6.25	7.50	7.50	7.50
Para red, tech.	lb.	.20	.20	.20	.20
Para red, toners, conc. (cwt.)	lb.	1.65	1.90	2.00	1.75
Phenol	lb.	.27	.23	.17	.11
p-Phenylenediamine	lb.	2.50	2.65	2.55	2.20
Phosphorus, yellow	lb.	.35	.35	.35	.30
Phthalic anhydride	lb.	.75	.45	.50	.65
Potassium bichromate	lb.	.34	.45	.34	.22
bromide [a]	lb.	.90	.95	.75	.47
(import., resale) [a]	lb.	.90	.95	.72	.43
carbonate, 80-85%, calc.	lb.	.21	.18	.18	.16½
chlorate (dom.)	lb.	.15	.15	.16	.18
(import.)	lb.	.16	.14½	—	.12
hydroxide (dom.)	lb.	.28	.28	.25	.20
(import.)	lb.	.32	.28	.23	.16
iodide	lb.	3.10	3.35	3.35	3.00
permanganate	lb.	.70	.90	.75	.60
prussiate, red	lb.	.90	.83	.80	.55
salts, fertil., *see* Appendix XXV					
Prussian blue (500 lb. lots)	lb.	.90	.95	.95	.82
Pyrites, Span., unwashed fines, crude (ex-ship)	unit	.16½	.18	.13	.13½
Quebracho, liq., 35%	lb.	.05½	.06	.06	.05
solid	lb.	.11	.12	.12	.12
Quinine sulfate [a]	oz.	.90	.90	.90	.70
(import., resale) [a]	oz.	.85	.90	.83	.50
R salt	lb.	1.75	2.00	1.70	1.75
Rochelle salt	lb.	.39	.39	.39	.33
Rosin, F grade (280 lb.)	bbl.	17.85	20.25	15.25	10.50
Saccharin	lb.	3.00	3.50	3.50	2.75
Sal ammoniac, white, gran.	lb.	.15	.15	.15	.11½
Salt cake, ground (bbl.)	ton	21.00	35.00	48.00	28.00
Saltpeter	cwt.	3.85	3.85	3.60	2.90
Santonin	lb.	120.00	160.00	160.00	80.00
Soda ash (makers) light, 48% (works)	cwt.	—	—	—	—
(resale) light, 58% (flat)	cwt.	2.50	3.50	3.00	1.80
caustic, *see* Sodium hydroxide					
Sodium benzoate, U.S.P.	lb.	.75	.75	.75	.70
bichromate	lb.	.26	.33	.20½	.09
bromide, U.S.P. [a]	lb.	.75	.85	.65	.43
(import., resale) [a]	lb.	.75	.85	.63	.38
cyanide, 96-98% (128%)	lb.	.25	.27	.60	.27
hydroxide (makers) 60% (works)	cwt.	—	—	—	—
(resale) 76% (flat)	cwt.	5.00	6.50	4.80	3.80
hyposulfite (bbl.)	cwt.	3.60	3.40	3.75	3.75
nitrate	cwt.	3.85	3.85	3.60	2.90
nitrite	lb.	.25	.20	.13½	.07¾
prussiate, yellow	lb.	.25	.32	.28	.20
salicylate [a]	lb.	.60	.60	.60	.50
silicate, cryst., 40°	lb.	1.10 cwt.	1.20 cwt.	1.20 cwt.	1.25 cwt.
sulfide, 60%	lb.	.05	.10¼	.09½	.07¼
Spruce, 25% tannin	lb.	.01	.01	.01	.01
Strychnine sulfate [a]	oz.	1.40	1.55	1.55	1.55
Sulfur, crude (N. Y.)	ton	25.00	25.00	25.00	20.00
Superphosphate (bulk)	ton	19.00	18.50	21.00	18.00
Terpineol, C.P. [a]	lb.	1.50	1.50	1.25	1.10
Thymol	lb.	12.00	13.00	11.50	10.00
Tin, crystals	lb.	.43	.43	.43	.40
Straits (spot)	cwt.	60.50	52.25	47.50	33.50
p-Toluidine	lb.	.75	.90	.90	.85
Toluidine, toner	lb.	3.75	4.25	4.25	3.25
Turpentine, spirit	gal.	1.94	2.45	1.55	.97
Ultramarine blue (bbl.)	lb.	.15	.15	.15	.15
Vanillin [a]	oz.	.95	.95	.90	.80
Vermilion, Chinese	lb.	—	—	—	—
Eng.	lb.	1.35	1.70	1.55	1.00
Zinc (open market, spot)	cwt.	9.20	8.50	8.40	5.75
chloride, fused	lb.	.08	.08	.08	.08
oxide, Am.	lb.	.12	.09½	.10½	.08½

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

PRICE LIST OF 155 IMPORTANT CHEMICALS AND RELATED PRODUCTS (*Cont.*)

		1921			
		Mar.	June	Sept.	Dec.
Acetanilide, U.S.P.	lb.	.28	.25	.29	.29
Acetone, drums	lb.	.12	.13	.13	.13
Acid, acetic, 28% (bbl.)	cwt.	2.75	2.75	2.50	2.50
acetylsalicylic (bulk)	lb.	.60	.58	.60	.70
benzoic	lb.	.70	.65	.65	.60
boric, cryst. (bbl.)	lb.	.13	.13	.12½	.12½
citric (makers)	lb.	.47	.47	.47	.47
(import., resale)	lb.	.45	.43	.45	.44
hydrochloric, 22° (carlots, carboys)	cwt.	2.10	1.80	1.90	1.90
nitric, 42° (carlots, carboys)	cwt.	7.50	7.25	7.00	6.75
oxalic, cryst	lb.	.17	.16	.16	.14½
phosphoric, 85%	lb.	.26	.25	.23	.16
picric (kegs)	lb.	.30	.20	.20	.20
salicylic[a]	lb.	.24	.22	.20	.24
stearic, T.P.	lb.	.13½	.10½	.11½	.10½
sulfuric, 66° (tanks, works)	ton	20.00	18.00	18.00	17.00
tannic, U.S.P. (bulk)	lb.	1.20	.90	.80	.75
tech.	lb.	.45	.45	.40	.35
tartaric (import.)	lb.	.33	.28	.27	.27
Acid phosphate (bulk)	ton	15.00	11.50	12.00	10.00
Alcohol, U.S.P., 190°	gal.	4.90	4.75	4.65	4.75
Alizarin lake, conc.	lb.	3.35	3.35	2.75	2.75
Alum, ammonia, lump	lb.	.04½	.04	.03½	.03½
potash, lump	lb.	.05½	.04	.03¾	.03¾
Aluminum, virgin	cwt.	23.50	23.00	20.00	17.00
hydrate, heavy	lb.	.08½	.08	.08	.08
light	lb.	.22	.22	.22	.20
sulfate, iron-free	cwt.	3.50	3.00	2.50	2.50
Ammonia, water, 26° (carlots, drums)	lb.	.07¾	.07¾	.07¾	.07¾
Ammonium chloride, white, gran	lb.	.07½	.06½	.05¾	.07
sulfate (double bags, f.a.s.)	cwt.	3.25	2.25	2.15	2.60
Aniline oil	lb.	.22	.19	.18	.17
salt	lb.	.28	.25	.25	.24
Antimony, crimson	lb.	.40	.40	.40	.40
Antipyrine (bulk)	lb.	1.50	1.90	2.10	1.50
Argols	lb.	.10	.10	.10	.10
Arsenic, white	lb.	.09	.07	.06½	.06
Aspirin (bulk)	lb.	.60	.58	.60	.70
Barium chloride (dom.)	ton	85.00	85.00	60.00	52.00
(import.)	ton	65.00	65.00	45.00	50.00
Barytes, prime white, floated (dom.)	ton	24.50	24.50	23.00	23.00
(import.)	ton	25.00	30.00	28.00	35.00
Benzaldehyde, U.S.P.[a]	lb.	1.00	1.50	1.50	1.25
Benzene, pure (carlots)	gal.	.30	.30	.27	.27
Benzidine base	lb.	.85	1.00	1.00	.90
Bismuth subnitrate[a]	lb.	2.00	2.00	2.00	1.85
Bleaching powder (spot)	cwt.	2.75	2.25	2.05	2.50
Blue vitriol	cwt.	5.25	5.25	5.00	5.55
Borax, cryst., gran., powd. (bbl.)	lb.	.06½	.05¾	.05¾	.05¾
Bromine, tech. (bulk)	lb.	.40	.27	.27	.27
Cadmium sulfide, yellow (cwt.)	lb.	1.20	1.20	1.25	1.25
Caffeine	lb.	6.50	5.50	4.75	4.25
Calcium chloride (f.s.d., N. Y.)	ton	28.75	28.75	28.75	28.75
sulfate, U.S.P.[a]	cwt.	2.50	2.50	2.50	2.50
Calomel[a]	lb.	1.00	.87	.82	.82
Camphor, Jap., ref.	lb.	.74	.67	.70	.90
Carbon bisulfide	lb.	.07	.07	.06½	.06½
black	lb.	.10½	.10½	.10½	.10½
tetrachloride	lb.	.10½	.11¼	.10½	.10½
Chestnut, clarif., 25% tannin	lb.	.02½	.02	.01¾	.01¾
Chlorine, liq.	lb.	.08	.08	.08	.08
Chlorobenzene	lb.	.12	.12	.12	.10
Chloroform	lb.	.40	.38	.36	.36
Cocaine hydrochloride	oz.	9.00	8.00	6.50	6.00
Codeine sulfate	oz.	6.70	5.30	4.90	4.90
Copper, Prime Lake	cwt.	13.00	13.00	12.00	13.75
sulfate	cwt.	5.25	5.25	5.00	5.55
Copperas (works)	cwt.	1.00	.75	.75	.75
Coumarin	lb.	4.75	4.75	4.35	3.75
Cream of tartar, U.S.P.	lb.	.30	.30	.27	.27
Cresol, U.S.P.	lb.	.17	.14	.14	.14
o-Cresol, cryst.	lb.	.18	.22	.24	.22
Dimethylaniline	lb.	.55	.42	.45	.45
Dinitrobenzene	lb.	.33	.25	.25	.21
Diphenylamine	lb.	.60	.60	.65	.65
Epsom salt, U.S.P.[a]	cwt.	2.50	2.50	2.50	2.50
Ether, U.S.P. IX	lb.	.18 conc. cwt.	.18 conc. cwt.	.16 conc. cwt.	.14 conc. cwt.
Eucalyptol	lb.	1.00	.85	.85	.90
Formaldehyde	lb.	.20	.15	.12	.10½
Glycerin, C.P. (drums)	lb.	.19	.16½	.14	.15
Hemlock, 25% tannin	lb.	.04½	.04½	.04	.04
Indigo, Bengal	lb.	2.15	2.15	2.15	Nom.
Madras	lb.	.80	.80	.80	.90
synth., 20% paste	lb.	.65	.85	.60	.60
Iodine, resublimed	lb.	3.75	3.60	3.50	3.50

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

		1921			
		Mar.	June	Sept.	Dec.
Lead (open market)	cwt.	4.00	5.00	4.40	4.70
acetate, white, cryst.	lb.	.15	.13	.12	.12
carbonate, dry	lb.	.08	.08	.08	.06½
Lime acetate	cwt.	2.00	2.00	2.00	1.75
Lithium carbonate	lb.	1.50	1.40	1.40	1.40
Lithopone	lb.	.06	.06	.06	.06
Logwood, stick	ton	30.00	30.00	30.00	28.00
Magnesium carbonate, U.S.P. (kegs)	lb.	.15	.14	.12	.12
sulfate, tech. (dom.)	cwt.	2.25	2.25	2.00	1.85
(import.)	cwt.	1.75	1.10	1.15	1.05
Menthol	lb.	4.40	3.75	4.30	4.75
Mercury	flask	46.00	47.00	37.00	47.00
chloride [a]	lb.	1.00	.87	.82	.82
Morphine sulfate [a]	oz.	5.30	5.30	4.90	4.90
Musk ketone	lb.	25.00	22.00	15.00	12.00
Naphtha, solvent	gal.	.28	.25	.25	.25
Naphthalene, flake	lb.	.08½	.08	.06½	.06½
β-Naphthol	lb.	.34	.38	.32	.30
α-Naphthylamine	lb.	.38	.38	.35	.27
p-Nitroaniline	lb.	.85	.80	.79	.77
Nitrotoluene	lb.	—	—	—	—
Opium, U.S.P. (cases)	lb.	6.00	5.50	5.50	5.50
Para red, tech.	lb.	.20	.20	.18	.18
Para red, toners, conc. (cwt.)	lb.	1.70	1.60	1.40	1.40
Phenol	lb.	.10	.09	.08	.10
p-Phenylenediamine	lb.	1.75	1.75	1.70	1.60
Phosphorus, yellow	lb.	.30	.35	.35	.30
Phthalic anhydride	lb.	.55	.55	.40	.40
Potassium bichromate	lb.	.13¾	.12	.11½	.10½
bromide [a]	lb.	.47	.24	.24	.19
(import., resale) [a]	lb.	.18	.16	.15	.14
carbonate, 80-85%, calc.	lb.	.08½	.05¾	.05	.04½
chlorate (dom.)	lb.	.18	.12	.12	.12
(import.)	lb.	.08½	.09	.06½	.05½
hydroxide (dom.)	lb.	.18	.12	.12	.08
(import.)	lb.	.10	.06½	.04½	.05½
iodide	lb.	2.60	2.60	2.65	2.75
permanganate	lb.	.45	.27	.23	.15
prussiate, red	lb.	.45	.30	.28	.26
salts, fertil., *see* Appendix XXV					
Prussian blue (500 lb. lots)	lb.	.60	.55	.50	.50
Pyrites, Span., unwashed fines, crude (ex-ship)	unit	.14	.14	.13	.13
Quebracho, liq., 35%	lb.	.04½	.04½	.04½	.03¾
solid	lb.	.05¾	.04¾	.03½	.04½
Quinine sulfate [a]	oz.	.70	.70	.70	.70
(import., resale) [a]	oz.	.62	.66	.65	.68
R salt	lb.	1.25	1.25	1.25	1.25
Rochelle salt	lb.	.27	.25	.20	.19
Rosin, F grade (280 lb.)	bbl.	6.75	5.75	5.30	5.55
Saccharin	lb.	1.65	2.00	2.00	2.05
Sal ammoniac, white, gran	lb.	.07½	.06½	.05¾	.07
Salt cake, ground (bbl.)	ton	25.00	17.00	17.00	18.00
Saltpeter	cwt.	2.75	2.70	2.15	2.25
Santonin	lb.	88.00	122.00	120.00	145.00
Soda ash (makers) light, 48% (works)	cwt.	1.72½	1.72½	1.62½	1.50
(resale) light, 58% (flat)	cwt.	2.10	2.00	2.15	1.85
caustic, *see* Sodium hydroxide					
Sodium benzoate, U.S.P.	lb.	.65	.55	.55	.55
bichromate	lb.	.08½	.08½	.07¾	.08
bromide, U.S.P. [a]	lb.	.43	.25	.25	.20
(import., resale) [a]	lb.	.20	.21	.17	.16
cyanide, 96-98% (128%)	lb.	.25	.23	.23	.27
hydroxide (makers) 60% (works)	cwt.	3.50	3.25	3.25	2.90
(resale) 76% (flat)	cwt.	3.60	3.85	4.00	3.85
hyposulfite (bbl.)	cwt.	3.75	3.75	3.50	3.50
nitrate	cwt.	2.75	2.70	2.15	2.25
nitrite	lb.	.06	.07¾	.07	.06¾
prussiate, yellow	lb.	.14½	.11½	.12	.14½
salicylate [a]	lb.	.31	.28	.26	.30
silicate, cryst., 40°	lb.	1.15 cwt.	1.10 cwt.	1.00 cwt.	1.00 cwt.
sulfide, 60%	lb.	.07	.05¾	.04¼	.04¼
Spruce, 25% tannin	lb.	.01	.01	.01	.01
Strychnine sulfate [a]	oz.	1.55	1.55	1.35	1.35
Sulfur, crude (N. Y.)	ton	20.00	20.00	20.00	20.00
Superphosphate (bulk)	ton	15.00	11.50	12.00	10.00
Terpineol, C.P. [a]	lb.	.75	.47½	.45	.45
Thymol	lb.	8.50	6.25	5.50	5.00
Tin, crystals	lb.	.30	.27½	.27	.27
Straits (spot)	cwt.	30.00	33.37½	26.00	31.12
p-Toluidine	lb.	.85	.70	.60	.60
Toluidine, toner	lb.	3.00	3.25	2.75	2.50
Turpentine, spirit	gal.	.56½	.66	.65	.80
Ultramarine blue (bbl.)	lb.	.12	.10	.10	.10
Vanillin [a]	oz.	.62½	.50	.50	.60
Vermilion, Chinese	lb.	—	—	—	—
Eng.	lb.	1.00	.90	.75	.80
Zinc (open market, spot)	cwt.	5.10	5.20	4.50	4.80
chloride, fused	lb.	.08	.08	.05¾	.04½
oxide, Am.	lb.	.08¼	.08¼	.08	.08

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

Price List of 155 Important Chemicals and Related Products (*Cont.*)

		1922			
		Mar.	June	Sept.	Dec.
Acetanilide, U.S.P.	lb.	.31	.30	.30	.35
Acetone, drums	lb.	.10	.10	Nom.	Nom.
Acid, acetic, 28% (bbl.)	cwt.	2.50	2.25	2.67½	3.17½
acetylsalicylic (bulk)	lb.	.75	.76	.85	1.00
benzoic	lb.	.60	.55	.55	.65
boric, cryst. (bbl.)	lb.	.11	.11	.11	.11
citric (makers)	lb.	.45	.45	.45	.50
(import., resale)	lb.	.45	.44½	.44½	.50
hydrochloric, 22° (carlots, carboys)	cwt.	1.80	1.45	1.45	1.75
nitric, 42° (carlots, carboys)	cwt.	6.75	7.25	7.25	7.25
oxalic, cryst	lb.	.12	.14	.17	.14
phosphoric, 85%	lb.	.17	.15	.16	.15¾
picric (kegs)	lb.	.20	.20	.20	.20
salicylic[a]	lb.	.24	.26	.29	.40
stearic, T.P.	lb.	.10½	.10½	.10½	.12½
sulfuric, 66° (tanks, works)	ton	16.00	14.00	14.00	14.00
tannic, U.S.P. (bulk)	lb.	.65	.70	.75	.80
tech.	lb.	.37	.35	.38	.40
tartaric (import.)	lb.	.26	.29	.28	.30½
Acid phosphate (bulk)	ton	8.50	8.00	8.00	9.50
Alcohol, U.S.P., 190°	gal.	4.80	4.70	4.70	4.70
Alizarin lake, conc.	lb.	2.75	2.75	2.75	2.75
Alum, ammonia, lump	lb.	.03½	.03½	.03½	.03½
potash, lump	lb.	.05	.04¼	.04½	.04½
Aluminum, virgin	cwt.	19.10	17.50	17.50	22.50
hydrate, heavy	lb.	.08	.08	.06½ bbl.	.06½ bbl.
light	lb.	.20	.17	.17	.16
sulfate, iron-free	cwt.	2.50	2.25	2.25	2.50
Ammonia, water, 26° (carlots, drums)	lb.	.07½	.07½	.07½	.07½
Ammonium chloride, white, gran.	lb.	.07½	.07¾	.07¾	.07¾
sulfate (double bags, f.a.s.)	cwt.	2.25	2.90	3.20	3.20
Aniline oil	lb.	.16	.14	.14	.16
salt	lb.	.22	.22	.21	.24
Antimony, crimson	lb.	.40	.40	.35	.45
Antipyrine (bulk)	lb.	1.75	2.10	2.00	2.30
Argols	lb.	.10	.08	.07	.07
Arsenic, white	lb.	.07	.07¼	.08½	.15
Aspirin (bulk)	lb.	.75	.76	.85	1.00
Barium chloride (dom.)	ton	60.00	100.00	95.00	100.00
(import.)	ton	60.00	95.00	85.00	95.00
Barytes, prime white, floated (dom.)	ton	23.00	23.00	23.00	26.00
(import.)	ton	32.00	32.00	32.00	32.00
Benzaldehyde, U.S.P.[a]	lb.	1.25	1.40	1.40	1.40
Benzene, pure (carlots)	gal.	.29	.29	.30	.30
Benzidine base	lb.	.90	.85	.85	.85
Bismuth subnitrate[a]	lb.	2.00	2.15	2.30	2.65
Bleaching powder (spot)	cwt.	2.00	1.60	1.75	2.00
Blue vitriol	cwt.	5.40	5.95	5.90	5.75
Borax, cryst., gran., powd. (bbl.)	lb.	.05½	.05½	.05½	.05½
Bromine, tech. (bulk)	lb.	.27	.25	.25	.25
Cadmium sulfide, yellow (cwt.)	lb.	1.50	1.60	1.50	1.50
Caffeine	lb.	3.75	3.75	3.75	3.75
Calcium chloride (f.a.d., N. Y.)	ton	24.75	24.50	24.50	24.50
sulfate, U.S.P.[a]	cwt.	2.50	2.50	2.50	2.75
Calomel[a]	lb.	.82	.94	1.00	1.15
Camphor, Jap., ref.	lb.	.92	.78	.83	.94
Carbon bisulfide	lb.	.06	.06	.06	.06
black	lb.	.10½	.16	.16	.16
tetrachloride	lb.	.10½	.09½	.10	.10½
Chestnut, clarif., 25% tannin	lb.	.01¾	.01½	.01½	.02
Chlorine, liq.	lb.	.06 carlots, cylinders	.05 carlots, cylinders	.05 carlots, cylinders	.05¼ carlots, cylinders
Chlorobenzene	lb.	.10	.08	.08	.08
Chloroform	lb.	.43	.30	.25	.35
Cocaine hydrochloride	oz.	6.00	6.00	6.00	7.07
Codeine sulfate	oz.	4.90	4.90	5.85	5.85
Copper, Prime Lake	cwt.	12.75	14.00	14.00	14.00
sulfate	cwt.	5.40	5.95	5.90	5.75
Copperas (works)	cwt.	.75 bulk	.85 bulk	.85 bulk	1.00 bulk
Coumarin	lb.	3.25	3.00	3.50	4.00
Cream of tartar, U.S.P.	lb.	.23	.23	.23	.24½
Cresol, U.S.P.	lb.	.12	.12	.12	.12
o-Cresol, cryst.	lb.	.16	.16	.16 drums	.18 drums
Dimethylaniline	lb.	.38	.36	.30	.39
Dinitrobenzene	lb.	.21	.20	.20	.19
Diphenylamine	lb.	.60	.58	.54	.52
Epsom salt, U.S.P.[a]	cwt.	2.50	2.50	2.50	2.75
Ether, U.S.P. IX	lb.	.14 conc. cwt.	.14 conc. cwt.	.14 conc. cwt.	.14 conc. cwt.
Eucalyptol	lb.	.85	.80	.80	.80
Formaldehyde	lb.	.09	.07½	.09	.14¼
Glycerin, C.P. (drums)	lb.	.16	.14½	.17	.18½
Hemlock, 25% tannin	lb.	.04	.04	.04	.04
Indigo, Bengal	lb.	Nom.	Nom.	—	—
Madras	lb.	.90	.85	.85	.85
synth., 20% paste	lb.	.60	.50	.45	.25
Iodine, resublimed	lb.	4.05	4.20	4.40	4.40

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

		1922			
		Mar.	June	Sept.	Dec.
Lead (open market)	cwt.	4.70	5.80	5.90	7.20
acetate, white, cryst.	lb.	.11	.10½	.10½	.12
carbonate, dry	lb.	.07¼	.07¼	.07¾	.08½
Lime acetate	cwt.	1.75	1.75	2.35	3.50
Lithium carbonate	lb.	1.40	1.40	1.50	1.50
Lithopone	lb.	.06	.06	.06	.06
Logwood, stick	ton	28.00	28.00	28.00	28.00
Magnesium carbonate, U.S.P. (kegs)	lb.	.12	.12	.13	.10½
sulfate, tech. (dom.)	cwt.	1.85	1.85	1.85	1.85
(import.)	cwt.	1.00	.90	.90	1.10
Menthol	lb.	5.25	5.50	6.25	11.00
Mercury	flask	51.00	55.00	66.00	72.00
chloride[a]	lb.	.82	.94	1.00	1.15
Morphine sulfate[a]	oz.	4.90	4.90	5.35	5.35
Musk ketone	lb.	9.00	9.00	9.00	14.00
Naphtha, solvent	gal.	.25	.27	.27	.27
Naphthalene, flake	lb.	.07½	.07	.07	.06
β-Naphthol	lb.	.28	.23	.22	.23
α-Naphthylamine	lb.	.30	.30	.30	.28
p-Nitroaniline	lb.	.77	.75	.75	.73
Nitrotoluene	lb.	—	—	—	—
Opium, U.S.P. (cases)	lb.	5.75	6.00	6.25	6.75
Para red, tech.	lb.	.18	.16	.16	.16
Para red, toners, conc. (cwt.)	lb.	1.40	1.25	1.00	1.00
Phenol	lb.	.12½	.12	.20	.35
p-Phenylenediamine	lb.	1.50	1.50	1.50	1.50
Phosphorus, yellow	lb.	.35	.25	.25	.35
Phthalic anhydride	lb.	.35	.35	.35	.35
Potassium bichromate	lb.	.10	.09¾	.09¾	.10
bromide[a]	lb.	.19	.23	.22	.26
(import., resale)[b]	lb.	.14	.15	.12	.17
carbonate, 80-85%, calc.	lb.	.04½	.04¾	.04¾	.05½
chlorate (dom.)	lb.	.08	.08	.08	.09
(import.)	lb.	.05¼	.06½	.06½	.08½
hydroxide (dom.)	lb.	.08	.08	.09	.08
(import.)	lb.	.05¾	.05¾	.05½	.06⅜
iodide	lb.	3.15	3.30	3.45	3.60
permanganate	lb.	.14	.14	.14½	.15½
prussiate, red	lb.	.65	.85	.90	.95
salts, fertil., *see* Appendix XXV					
Prussian blue (500 lb. lots)	lb.	.50	.50	.55	.55
Pyrites, Span., unwashed fines, crude (ex-ship)	unit	.11½	.11½	.11½	.11½
Quebracho, liq., 35%	lb.	.03¾	.03¾	.03¾	.03¾
solid	lb.	.04½	.04¾	.04¾	.04¾
Quinine sulfate[a]	oz.	.60	.60	.50	.50
(import., resale)[a]	oz.	.58	.58	.50	.50
R salt	lb.	.60	.54	.50	.55
Rochelle salt	lb.	.18	.19	.17	.19
Rosin, F grade (280 lb.)	bbl.	5.35	6.20	6.40	6.35
Saccharin	lb.	1.90	1.90	1.90	1.90
Sal ammoniac, white, gran.	lb.	.07½	.07¾	.07¾	.07¾
Salt cake, ground (bbl.)	ton	17.00	18.00	21.00	25.00
Saltpeter	cwt.	2.35	2.65	2.55	2.55
Santonin	lb.	147.00	167.00	167.00	172.00
Soda ash (makers) light, 48% (works)	cwt.	1.25	1.25	1.20	1.20
(resale) light, 58% (flat)	cwt.	1.85	1.85	1.85	2.00
caustic, *see* Sodium hydroxide					
Sodium benzoate, U.S.P.	lb.	.52	.50	.50	.57
bichromate	lb.	.07¾	.07¼	.06¾	.07½
bromide, U.S.P.[a]	lb.	.20	.20	.19	.25
(import., resale)[a]	lb.	.15	.15	.13	.18
cyanide, 96-98% (128%)	lb.	.20	.20	.19	.25
hydroxide (makers) 60% (works)	cwt.	2.50	2.50	2.50	2.50
(resale) 76% (flat)	cwt.	3.30	3.85	3.60	3.70
hyposulfite (bbl.)	cwt.	3.25	3.10	3.10	3.45
nitrate	cwt.	2.35	2.65	2.55	2.55
nitrite	lb.	.08	.09	.09	.09½
prussiate, yellow	lb.	.18¼	.23	.22	.20½
salicylate[d]	lb.	.30	.32	.36	.47
silicate, cryst., 40°	lb.	.85 cwt.	.85 cwt.	.72½ cwt.	.72½ cwt.
sulfide, 60%	lb.	.05	.03¾	.03¼	.03¼
Spruce, 25% tannin	lb.	.01	.01	.01	.01
Strychnine sulfate[a]	oz.	.88	.76	.76	.84
Sulfur, crude (N. Y.)	ton	20.00	18.00	18.00	18.00
Superphosphate (bulk)	ton	8.50	8.00	8.00	9.50
Terpineol, C.P.[a]	lb.	.45	.50	.55	.55
Thymol	lb.	4.40	4.10	4.25	4.25
Tin, crystals	lb.	.28	.29	.29	.31
Straits (spot)	cwt.	29.75	32.12	31.87	37.25
p-Toluidine	lb.	1.00	1.00	.95	1.00
Toluidine, toner	lb.	2.50	2.10	2.10 kegs	2.10 kegs
Turpentine, spirit	gal.	.86	.96	1.26	1.43
Ultramarine blue (bbl.)	lb.	.10	.08	.08	.08
Vanillin[a]	oz.	.55	.50	.45	.43
Vermilion, Chinese	lb.	—	—	—	—
Eng.	lb.	.85	.90	1.20	1.30
Zinc (open market, spot)	cwt.	4.90	5.65	6.50	7.55
chloride, fused	lb.	.07	.05	.05½	.05½
oxide, Am.	lb.	.08	.08	.07	.07½

---

[a] Am. mfrs. price; [b] Aug. price; [c] Jan. 1 price; [d] Aug.-Sept. price.

Appendix III

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (pounds)

(From *O.P.D. Reptr. Ann. Rept. 1930.*)

Official data for fiscal years to June 30. Where figures missing, data unavailable because official records not kept. n.e.s. = not elsewhere specified; n.s.p.f. = not specially provided for.

Acenaphthene, fluorene, methylanthracene, & methylnaphthalene

1920..........	15,759	$946
1921..........	—	—
1922..........	100	64

Acetanilide (medical), acetphenetidine, & acetylsalicylic acid

1914..........	1,060	$164
1915..........	800	389
1916..........	—	—
1917..........	15	22
1918..........	—	—
1919..........	—	—
1920..........	—	—
1921..........	10	16
1922..........	20	12

Acetone, acetone oil, & ethyl methyl ketone

1914..........	2,760	$ 307
1915..........	235,917	21,105
1916..........	179,497	14,424
1917..........	—	—
1918..........	148,082	26,910
1919..........	443,504	80,986
1920..........	—	—
1921..........	6,654	311
1922..........	155	57

Acetphenetidine (Phenacetin)

1915..........	39,990	$27,356
1916..........	203	1,532
1917..........	3,280	40,352

Acid, acetic

1913..........	38,648	$ 3,036
1914..........	27,750	1,952
1915..........	312,850	16,419
1916..........	504,858	53,969
1917..........	201,604	28,492
1918..........	264,997	47,673
1919..........	1,252,649	224,482
1920..........	2,925,076	339,178
1921..........	859,755	108,090

Acid, acetic anhydride

1913..........	309,643	$51,632
1914..........	150,892	23,240
1915..........	3,652	1,019
1916..........	18,177	10,013
1917..........	9,060	7,485
1918..........	13,112	16,533
1919..........	10,948	14,780

Acid, acetylsalicylic

1914..........	22,841	$11,873
1915..........	112,602	53,792
1916..........	229	311
1917..........	501	2,136
1918..........	1,100	3,300
1919..........	26	76

Acid, aminosalicylic

1920..........	11,199	$8,182

Acid, arsenious, *see* Vol. III, Appendix XXX

Acid, benzoic (medicinal)

1913..........	863,015	$133,887
1914..........	278,896	51,701
1915..........	132,666	25,442
1916..........	25,155	79,856
1917..........	13,547	52,988
1918..........	2,354	16,390
1919..........	125	1,114
1920..........	313	1,461
1921..........	240	165
1922..........	11,023	2,847

Acid, boric

1913..........	362,400	$13,897
1914..........	527,201	22,390
1915..........	401,684	18,002
1916..........	424,219	22,145
1917..........	404,210	24,590
1918..........	195,650	14,087
1919..........	280,935	31,170
1920..........	253,958	11,165
1921..........	227,461	19,049
1922..........	1,046,926	82,785

Acid, carbolic (not phenol)

1917..........	495,813	$ 34,355
1918..........	127,574	11,198
1919..........	2,021,165	194,589
1920..........	157,319	13,243
1921..........	183,709	20,906
1922..........	315,406	31,675

Not stated after 1922.

Acid, carbolic (phenol), *see* Vol. II, Appendix XXIII

Acid, chromic, & anhydrides

1913..........	8,522	$1,682
1914..........	7,778	1,220
1915..........	6,505	1,394
1916..........	—	—
1917..........	—	—
1918..........	9,512	1,857
1919..........	—	—
1920..........	—	—
1921..........	1,100	90
1922..........	3,969	1,289

Acid, citric, *see* Vol. III, Appendix XI

Acid, formic, *see* Vol. III, Appendix XI

Acid, gallic, *see* Vol. III, Appendix XI

Acid, glycerophosphoric, salts & compounds

1914..........	24,789	$23,066
1915..........	15,933	17,678
1916..........	7,668	8,242
1917..........	5,853	9,249
1918..........	961	1,884
1919..........	2,630	6,967
1920..........	7,143	12,451
1921..........	8,287	10,229
1922..........	3,264	2,716

Acid, hydrochloric, *see* Vol. III, Appendix XI

Acid, hydrofluoric

1913..........	12	$ 5
1914..........	305	22
1915..........	150	11
1916..........	17	33
1917..........	—	—
1918..........	1	2

Acid, lactic, *see* Vol. III, Appendix XI

Acid, nitric, *see* Vol. III, Appendix IX

Acid, oxalic, *see* Vol. III, Appendix XI

Acid, phosphoric, *see* Vol. II, Appendix XXX

Acid, phthalic

1913..........	75,695	$20,511
1914..........	63,574	15,597
1915..........	17,925	4,498

Acid, pyrogallic, *see* Vol. III, Appendix XI

Acid, salicylic (medicinal), & salts

1913..........	31,844	$ 6,500
1914..........	18,821	4,425
1915..........	82,617	24,408
1916..........	160	386
1917..........	5,033	3,114
1918..........	21,354	20,883
1919..........	5	2
1920..........	—	—
1921..........	—	—
1922..........	2,240	1,775

Acid, silicic

1913..........	121,344	$6,486
1914..........	—	—
1915..........	3,086	586
1916..........	15	6
1917	—	—
1918..........	—	—
1919..........	—	—
1920..........	—	—
1921	110	17
1922..........	210	32
1923..........	100	17

Not stated after 1923.

Acid, stearic

1913..........	119,619	$12,160
1914..........	100,088	9,593
1915..........	32,795	3,465
1916..........	40,979	6,029
1917..........	538	75
1918..........	—	—
1919..........	—	—
1920..........	4,044	867
1921..........	12,662	1,750
1922..........	25,919	2,170

Acid, sulfuric (oil of vitriol), *see* Vol. III, Appendix V

Acid, tannic (medicinal), 50% or more tannic, *see* Vol. III, Appendix XI

Acid, tartaric, *see* Vol. III, Appendix X

Acid, valeric, *see* Vol. III, Appendix XI

Acids & anhydrides, n.s.p.f.

1913..........	—	$86,539
1914..........	—	94,078
1915..........	—	73,848

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Acids & anhydrides, n.s.p.f. (*Cont.*)

1916	—	$ 36,430
1917	—	85,257
1918	—	510,091
1919	14,025	58,915
1920	52,758	25,200
1921	106,746	28,096
1922	226,956	57,361

Aconite, crude

1913	12,946	$1,065
1914	4,267	321
1915	8,821	962
1916	6,720	538
1917	34,285	8,724
1918	475	119
1919	22,320	4,462
1920	31,471	8,881
1921	10,854	2,452
1922	10,645	1,367

Agar-agar

1914	189,232	$ 54,319
1915	344,119	92,809
1916	332,931	110,410
1917	431,622	162,527
1918	246,988	91,442
1919	338,307	172,832
1920	443,116	247,404
1921	199,584	98,722
1922	417,979	185,139

Alcohol, ethyl (pure grain)

1913	135,250	$22,780
1914	109,830	19,365
1915	40,532	5,707
1916	59,198	7,285
1917	4	8
1918	69	20
1919	290	289
1920	—	—
1921	27	34
1922	—	—

Proof gallons.

Alizarin, natural or artificial, & dyes therefrom

1913	8,219,087	$1,824,973
1914	806,764	246,196

Stated as following, after Oct. 3, 1913.

Alizarin & derivatives, natural or synthetic, & dyes therefrom

1914	1,828,074	$ 599,648
1915	5,992,878	1,586,367
1916	71,834	44,282
1917	99,057	127,240

Stated separately after 1917.

Alizarin assistant, etc., & soaps containing castor oil, etc.

1913	137,187	$62,923
1914	186,234	72,430
1915	48,376	18,820
1916	7,382	4,134
1917	5,193	3,010
1918	24	24
1919	47,008	32,121
1920	27	29
1921	1,147	711
1922	1,187	708

Gallons.

Alizarin, natural

1918	115,133	$160,775
1919	1,741	5,155
1920	4,943	3,457
1921	77,551	62,404
1922	62,928	116,773

Alizarin, synthetic

1918	19,180	$55,179
1919	—	—
1920	58,810	18,785
1921	122,246	45,221
1922	36,736	18,510

Alizarin colors or color lakes

1918	2,540	$ 11,208
1919	6,284	9,121
1920	19,634	17,161
1921	144,076	204,859
1922	61,452	46,411

Not stated after 1922.

Alizarin dyes

1918	2,759	$ 10,698
1919	4,025	3,397
1920	19,393	9,475
1921	89,011	117,983
1922	328,900	529,562

Alum, alum cake, patent alum, aluminum sulfate, & aluminous cake

1913	4,129,160	$39,944
1914	4,119,481	47,759
1915	3,904,561	41,166
1916	2,482,663	45,491
1917	1,636,989	56,768
1918	996,798	32,779
1919	220,967	7,915
1920	1,062,041	37,777
1921	3,069,682	71,135
1922	3,795,551	71,721
1923	2,750,253	48,192

Aluminum, crude, scrap & alloy

1913	26,642,112	$4,247,580
1914	16,421,076	2,801,911
1915	13,925,919	2,364,044
1916	8,203,895	1,823,106
1917	1,904,000	558,897
1918	1,503,360	480,782
1919	5,548,784	1,748,691
1920	30,853,386	9,595,122
1921	35,626,274	9,015,422
1922	24,697,080	4,805,767

Aluminum hydroxide (refined bauxite)

1913	2,252,156	$37,812
1914	1,639,027	26,328
1915	202,968	3,680
1916	418	260
1917	—	—
1918	94,278	7,562
1919	—	—
1920	—	—
1921	2,549	963
1922	15,816	569

Ambergris, under 10% alcohol

1913	608	$10,964
1914	32	695
1915	1	87
1917	160	2,771
1918	204	3,643
1919	494	1,097
1920	48	540
1921	20	916
1922	100	12,655

Aminonaphthol, -phenetole, -phenol

1919	590	$ 1,475
1920	438	942
1921	14,623	11,699
1922	—	—

Ammonia, anhydrous

1913	—	—
1914	—	—
1915	307	$ 35
1916	—	—
1917	200	46
1918	2,698	1,039
1919	—	—
1920	12,512	4,305
1921	14,038	6,120
1922	102	48

Ammonium carbonate & bicarbonate

1913	258,376	$16,173
1914	391,981	25,195
1915	784,821	49,122
1916	357,280	25,018
1917	244,840	$18,264
1918	76,160	6,732
1919	85,762	15,757
1920	271,787	32,288
1921	238,820	21,897
1922	742,067	38,005

Ammonium chloride

1913	10,387,148	$504,330
1914	9,254,539	470,566
1915	4,788,325	241,713
1916	1,965,464	122,174
1917	1,856,696	178,274
1918	1,000,262	97,994
1919	648,961	92,942
1920	5,295,692	563,130
1921	4,502,056	445,705
1922	6,647,610	338,555

Ammonium nitrate

1914	2,766,000	$ 132,849
1915	2,274,000	193,907
1916	—	—
1917	87,300	4,015
1918	74,101	4,287
1919	15,755	1,871
1920	18,292,080	1,360,153
1921	28,417,403	1,823,363
1922	44,724,215	2,628,308

Ammonium perchlorate

1914	70,253	$ 6,337
1915	72,576	6,515
1916	—	—
1917	275	53
1918	465	165
1919	1,768	402
1920	452,356	85,649
1921	4,502,050	413,470
1922	3,888,039	298,780

Ammonium phosphate

1913	7,433	$ 493
1914	205,764	13,462
1915	71,782	5,394
1916	810	40
1917	1,000	206
1918	1,316	336
1919	—	—
1920	—	—
1921	14,232	1,787
1922	27,947	2,980

Ammonium sulfate

1913	61,113	$3,660,064
1914	83,597	4,900,058
1915	64,417	3,215,139
1916	19,404	1,371,007
1917	8,176	647,271

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Ammonium sulfate (*Cont.*)

1918	3,983	$467,999
1919	1,964	288,469
1920	2,586	343,107
1921	2,537	226,300
1922	6,356	314,269

Tons.

Aniline oil

1913	2,015,318	$171,047
1914	1,444,772	116,628
1915	1,407,305	240,165
1916	104,836	28,130
1917	—	—
1918	—	—
1919	—	—
1920	—	—
1921	220	72
1922	11,243	1,799

Not stated after 1922.

Aniline salt

1913	4,976,108	$371,198
1914	3,083,467	222,728
1915	895,439	130,280
1916	16,084	3,978
1917	—	—
1918	21,273	3,250
1919	—	—
1920	—	—
1921	4	1
1922	18,316	12,109

Not stated after 1922.

Annatto & extracts

1913	405,024	$19,991
1914	507,250	25,341
1915	809,903	53,174
1916	603,271	69,811
1917	669,445	78,017
1918	749,782	73,294
1919	205,059	12,549
1920	917,932	38,927
1921	697,333	25,133
1922	856,731	34,226

Anthracene

1918	—	—
1919	95,025	$3,008

Stated separately after 1919.

Anthracene, under 30%

1920	7,551	$ 506
1921	197,367	17,012
1922	89,562	687

Anthracene, 30% and over

1920	39,439	$ 7,018
1921	822,740	98,448
1922	—	—

Anthracene & anthracene oil

1914	—	$32,175
1915	—	49,949
1916	—	2,551
1917	—	2,258

Stated separately after 1917.

Anthracene oil

1918	11,900	$2,010
1919	11,185	2,260
1920	12,694	3,284
1921	18,405	6,725
1922	8,513	2,050

Gallons.

Anthracene & carbazole colors, & dyes therefrom

1917	399,300	$426,198
1918	35,733	28,018
1919	65,808	82,720
1920	84,751	120,774
1921	464,042	704,954
1922	430,282	828,746

Anthraquinone, aminoanthraquinone, nitroanthraquinone

1920	3,147	$ 2,643
1921	46,327	21,422
1922	93,153	62,445

Antimony oxide, salts, & compounds

1913	1,819,323	$ 97,447
1914	2,623,084	248,164
1915	1,797,265	219,605
1916	511,848	109,814
1917	192,099	46,190
1918	37,724	13,744
1919	267,885	11,378
1920	569,052	20,274
1921	315,427	18,256
1922	63,296	5,859
1923	3,579,780	245,110

Antipyrine

1914	7,686	$ 11,608
1915	606	1,085
1916	222	2,202
1917	6,429	46,110
1918	22,736	92,653
1919	14,487	160,902
1920	15,656	72,556
1921	3,836	16,194
1922	7,096	10,293

Antitoxins, vaccines, serums, viruses, & bacterins

1913..........	—	$ 5,032
1914..........	—	19,019
1915..........	—	12,826
1916..........	—	8,225
1917..........	—	11,460
1918..........	—	6,009
1919..........	—	6,076
1920..........	—	6,907
1921..........	—	7,314
1922..........	—	2,645

Apatite

1913..........	2,930	$22,535
1914..........	92	796
1915..........	—	—
1916..........	—	—
1917..........	—	—
1918..........	—	—
1919..........	29	825
1920..........	70	2,648
1921..........	72	2,286
1922..........	—	—

Tons.

Argols, crude tartar, or wine lees, *see* Vol. III, Appendix X

Arsenic sulfide, realgar, & orpiment

1913..........	8,475,592	$354,284
1914..........	4,148,928	169,614
1915..........	3,981,661	178,756
1916..........	2,794,254	122,795
1917..........	2,373,701	172,811
1918..........	7,691,028	654,282
1919..........	7,038,146	563,335
1920..........	6,470,700	472,710
1921..........	8,801,293	794,215
1922..........	7,520,571	471,296

Ashes, wood, & beet root

1913..........	—	$36,493
1914..........	—	27,884
1915..........	—	41,522
1916..........	—	43,839
1917..........	—	55,226
1918..........	—	47,932
1919..........	7,302,539	49,276
1920..........	8,537,614	44,175
1921..........	6,212,848	38,609
1922..........	5,043,755	23,172

Barite, manufactured

1913..........	4,594	$36,819
1914..........	5,379	42,627
1915..........	1,755	14,997
1916..........	—	2
1917..........	210	$ 3,813
1918..........	—	—
1919..........	—	—
1920..........	107	653
1921..........	509	10,519
1922..........	1,579	24.440

Tons.

Barite, unmanufactured

1913..........	28,358	$ 63,345
1914..........	32,550	63,270
1915..........	9,616	21,087
1916..........	15	245
1917..........	—	—
1918..........	5	63
1919..........	35	245
1920..........	2,058	10,405
1921..........	23,238	156,987
1922..........	9,500	64,763

Tons.

Barium carbonate, precipitated

1913..........	2,182,517	$ 20,143
1914..........	4,995,451	46,425
1915..........	344,588	7,864
1916..........	6	2
1917..........	804	177
1918..........	106,288	1,437
1919..........	—	—
1920..........	163,509	18,268
1921..........	1,816,693	45,859
1922..........	7,806,346	135,185

Barium chloride

1913..........	2,926,159	$ 26,341
1914..........	6,110,386	64,563
1915..........	4,686,029	60,532
1916..........	50	10
1917..........	6,614	608
1918..........	—	—
1919..........	3,290	783
1920..........	2,520,321	81,988
1921..........	2,779,966	113,695
1922..........	4,905,453	81,713

Barium dioxide

1913..........	3,507,508	$215,500
1914..........	6,085,798	329,139
1915..........	4,084,144	317,262
1916..........	546,442	48,451
1917..........	—	—
1918..........	—	—
1919..........	—	—
1920..........	70,862	12,367
1921..........	684,640	89,138
1922..........	1,917,370	179,057

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Barium sulfate, precipitated (blanc fixe)

1913..........	4,808,726	$58,499
1914..........	4,752,474	60,641
1915..........	2,233,369	25,748
1916..........	492,723	11,523
1917..........	408,163	10,029
1918..........	179,200	2,376
1919..........	1,285	90
1920..........	41,108	1,267
1921..........	1,090,364	19,291
1922..........	3,651,152	55,643

Bark, *see* Cinchona; Mangrove

Bauxite, crude

1913..........	30,863	$119,848
1914..........	23,576	86,871
1915..........	12,870	50,557
1916..........	3,450	17,194
1917..........	6,403	22,568
1918..........	2,238	10,045
1919..........	2,744	10,577
1920..........	11,748	77,391
1921..........	59,135	343,909
1922..........	11,644	52,468

Tons.

Bauxite, refined, *see* Aluminum hydroxide

Beeswax & other animal wax

1913..........	828,287	$ 254,704
1914..........	1,412,695	477,745
1915..........	1,565,338	440,047
1916..........	2,284,283	618,856
1917..........	2,711,514	904,557
1918..........	1,950,513	678,148
1919..........	2,100,458	783,716
1920..........	3,919,810	1,354,782
1921..........	2,215,332	693,551
1922..........	3,100,971	580,723

Benzaldehyde, *see* Naphthol, beta

Benzene

1917..........	3,175,906	$273,108
1918..........	3,073,948	216,640
1919..........	1,509,861	38,209
1920..........	170,519	2,547
1921..........	1,717,936	42,537
1922..........	458,949	9,651

Benzine, *see* Oil, mineral

Benzyl chloride

1920..........	1,150	$452

Bismuth

1913..........	151,030	$257,176
1914..........	131,190	241,448
1915..........	34,237	72,587
1916..........	64,281	155,925
1917..........	88,465	196,113
1918..........	75,611	207,098
1919..........	76,539	218,376
1920..........	75,781	97,489
1921..........	96,692	159,670
1922..........	97,470	158,760

Blanc fixe, *see* Barium sulfate

Bleaching powder, *see* Lime, chlorinated

Blood, dried

1914..........	—	$391,947
1915	—	227,648
1916..........	—	196,600
1917..........	—	379,067
1918..........	—	479,518
1919	14,281,776	518,630
1920	18,457,336	678,948
1921	7,412,909	290,609
1922..........	15,085,485	337,349

Blues: Berlin, Prussian, Chinese, etc.

1914..........	275,174	$ 50,149
1915..........	547,299	112,904
1916..........	185,294	110,901
1917..........	373,074	209,524
1918..........	13,867	15,009
1919..........	8,222	5,879
1920..........	297,256	120,726
1921..........	275,757	124,204
1922..........	20,617	7,113

Bones, crude, steamed, or ground

1913..........	—	$ 565,566
1914..........	—	829,730
1915..........	—	756,015
1916..........	—	755,700
1917..........	—	826,142
1918..........	—	1,010,871
1919..........	26,275,886	369,583
1920..........	94,593,269	1,500,142
1921..........	155,409,170	2,526,323
1922..........	41,202,190	450,649

Bone black, lampblack, etc.

1913..........	—	$31,056
1914..........	—	27,604
1915..........	—	24,459
1916..........	—	2,396

1917	—	$ 6,388
1918	—	279
1919	69,977	5,118
1920	318,272	26,663
1921	439,126	28,757
1922	518,809	25,717
1923	1,787,243	119,068

Bone black, bone char, blood char (decolorizing, non-pigment)

1913	—	$ 12,484
1914	—	77,717
1915	—	120,715
1916	—	86,724
1917	—	80,163
1918	—	11,865
1919	—	69,813
1920	—	312,330
1921	—	433,712
1922	—	80,812

Bone dust, bone meal, animal carbon & ash (fertilizer)

1913	33,919	$ 818,307
1914	41,446	1,036,493
1915	23,440	584,748
1916	20,595	527,079
1917	14,805	383,541
1918	8,428	285,882
1919	3,970	92,588
1920	6,867	248,176
1921	27,413	1,417,886
1922	18,234	495,445

Tons.

Borax, crude

1913	11,768	$ 882
1914	686	93
1915	—	—
1916	—	—
1917	83	3
1918	—	—
1919	—	—
1920	—	—
1921	—	—
1922	6,854,490	107,788

Borax, refined

1914	4,522	$ 641
1915	2,265	314
1916	682	112
1917	614	109
1918	2	1
1919	478	166
1920	30,334	2,423
1921	226,469	12,505
1922	767	255

Bronze or Dutch metal (leaf)

1913	763,071	$104,329
1914	792,578	110,316
1915	896,038	110,163
1916	291,396	38,559
1917	306,497	81,277
1918	473,835	136,394
1919	158,516	38,114
1920	246,944	71,535
1921	219,857	58,447
1922	158,028	32,586

In 100 leaves, 5½ × 5½ in.

Bronze powder, brocades, flitters, & metallics

1913	1,405,502	$420,308
1914	1,403,091	406,249
1915	1,063,206	288,054
1916	161,409	96,852
1917	524,032	283,976
1918	61,785	34,153
1919	11,099	5,093
1920	138,253	82,294
1921	745,041	288,435
1922	1,167,005	293,968

Browns: Spanish, Indian red, colcothar, or iron oxide

1913	—	$103,604
1914	—	186,476
1915	—	183,033
1916	—	221,209
1917	—	292,122
1918	—	333,516
1919	9,791,019	280,076
1920	11,277,278	362,288
1921	16,656,187	528,306
1922	17,936,324	589,329
1923	20,273,852	724,244

Not stated after 1923.

Browns: Vandyke, Cassel earth or Cassel brown

1913	—	$ 1,381
1914	—	2,663
1915	—	1,497
1916	—	365
1917	—	2,534
1918	—	854
1919	33,600	2,573
1920	373,456	21,181
1921	417,875	13,314
1922	327,400	7,514

Cadmium

1913	1,000	$1,508
1914	1,543	1,239
1915	264	278

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Cadmium (*Cont.*)

1916..........	5	$ 6
1917..........	—	—
1918..........	—	—
1919..........	—	—
1920..........	—	—
1921..........	101	216
1922..........	—	—

Caffeine

1913..........	59,773	$211,361
1914..........	80,350	260,323
1915..........	54,323	186,557
1916..........	1,267	15,228
1917..........	1,601	17,219
1918..........	6,471	64,529
1919..........	2,662	26,383
1920..........	2,992	14,884
1921..........	2,574	12,769
1922..........	8,519	34,655

Caffeine salts & non-coal-tar derivatives

1914..........	—	$9,712
1915..........	—	4,071
1916..........	—	605
1917..........	—	—
1918..........	—	—
1919..........	—	—
1920..........	—	—
1921..........	—	44
1922..........	—	1,195

Calcium

1920..........	21,648	$3,937
1921..........	2,269	2,692
1922..........	3,684	682

Calcium acetate, carbide, chloride, & nitrate

1914..........	—	$ 53,455
1915..........	—	1,208,394
1916..........	—	3,206,369
1917..........	—	3,808,281
1918..........	—	3,422,190
1919..........	74,915,529	2,920,293
1920..........	76,847,476	2,911,179
1921..........	111,261,888	4,466,039
1922..........	47,667,755	1,775,973
1923..........	41,360,410	1,481,787

Calcium cyanamide, *see* Vol. II, Appendix XVI

Calcium tartrate, crude, *see* Vol. III, Appendix X

Calomel, corrosive sublimate, & other mercurial medicinal preparations

1913..........	—	$42,728
1914..........	—	37,589
1915..........	—	25,694
1916..........	—	13,158
1917..........	—	9,974
1918..........	—	2,124
1919..........	—	915

Stated separately after 1919.

Calomel

1920..........	3,026	$3,254
1921..........	720	1,029
1922..........	2,581	1,876

Camphor, synthetic

1915..........	16	$ 3
1916..........	—	—
1917..........	469	174
1918..........	—	—
1919..........	—	—
1920..........	116,100	229,238
1921..........	123,686	23,060
1922..........	—	—

Carbazole, 65% and over

1920..........	259	$ 108
1921..........	—	—
1922..........	8,820	3,865

Carbon tetrachloride

1914..........	572,910	$28,300
1915..........	342,854	18,139
1916..........	—	—
1917..........	2	2
1918..........	—	—
1919..........	—	—
1920..........	—	—
1921..........	—	—
1922..........	144,472	3,956

Casein or Lactarene

1913..........	8,803,639	$ 651,062
1914..........	10,799,351	705,305
1915..........	7,919,742	498,897
1916..........	10,376,641	984,899
1917..........	12,319,111	1,843,492
1918..........	12,106,855	1,765,653
1919..........	8,125,135	959,995
1920..........	24,039,313	2,783,548
1921..........	14,179,764	1,570,069
1922..........	10,529,295	706,861

Casein compounds, galalith, etc.

1913	—	$ 12,736
1914	—	15,060
1915	—	10,048
1916	—	10,028
1917	—	30,762
1918	—	45,368
1919	—	75,883
1920	—	138,515
1921	—	58,016
1922	—	147,448

Cellophane (sheets)

1918	—	$ 5,046
1919	—	10,761
1920	—	6,585
1921	—	31,847
1922	—	12,957

Chalk, unmanufactured

1913	150,010	$120,049
1914	128,947	102,907
1915	120,225	91,188
1916	131,368	95,861
1917	143,216	131,385
1918	107,391	120,792
1919	84,539	117,796
1920	112,292	179,543
1921	123,672	233,408
1922	78,084	123,123

Tons.

Chalk, prepared

1913	—	$79,731
1914	—	52,656
1915	—	36,621
1916	—	46,135
1917	—	39,319
1918	—	42,390
1919	—	28,265

After 1919, see below.

Chalk, precipitated

1920	932,578	$23,863
1921	2,390,250	58,184
1922	2,801,299	70,090

Chalk, precipitated (medicinal, toilet)

1920	1,021,885	$27,899
1921	328,073	9,952
1922	95,170	1,779

Not stated after 1922.

China clay or crude kaolin

1913	263,838	$1,753,822
1914	241,936	1,590,054
1915	230,484	1,506,555
1916	228,936	1,376,990
1917	206,729	$1,212,099
1918	192,705	1,303,668
1919	146,260	1,436,786
1920	213,713	2,481,396
1921	247,267	2,805,865
1922	192,661	2,037,912

Tons.

Chloral hydrate

1913	—	—
1914	644	$ 241
1915	112	25
1916	1	2
1917	—	—
1918	1,057	1,599
1919	—	—
1920	—	—
1921	1,850	1,711
1922	55	57

Chloroform

1913	942	$1,643
1914	2,444	990
1915	26	43
1916	—	—
1917	—	—
1918	1	1
1919	54	40
1920	2	4
1921	—	—
1922	4,512	615

Chlorophyll extract

1912	4,461	$3,586
1913	7,508	8,544
1914	10,125	8,503
1915	3,490	3,671
1916	190	192
1917	—	—
1918	199	163
1919	363	511
1920	8	14
1921	1,248	2,242
1922	2,751	3,517

Chrome, chromium metal

1913	522	$ 89,291
1914	208	25,976
1915	81	6,943
1916	10	1,998
1917	10	1,851
1918	—	—
1919	—	—
1920	2,553,255	279,894
1921	2,945,624	315,504
1922	985,243	115,723

Tons prior to 1920.

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Chrome ore, *see* Vol. III, Appendix XV

Chrome colors, *see* Vol. III, Appendix XXVI

Cinchona bark

1913..........	3,329,973	$ 354,593
1914..........	3,654,968	464,411
1915..........	3,951,196	561,802
1916..........	3,967,320	777,637
1917..........	2,531,397	685,936
1918..........	3,121,958	779,403
1919..........	3,866,158	803,081
1920..........	5,242,724	1,132,874
1921..........	3,566,010	1,334,758
1922..........	766,589	276,833

Cinchona bark & alkaloids or salts, n.e.s.

1913..........	648,865	$131,692
1914..........	452,292	117,915
1915..........	203,330	66,004
1916..........	231,100	82,167
1917..........	623,947	324,438
1918..........	3,131,958	769,403
1919..........	1,147,102	272,631
1920..........	1,112,598	268,509
1921..........	1,666,688	504,489
1922..........	766,582	276,833

Ounces.

Cinchonidia (cinchonidine)

1913..........	309,395	$43,680
1914..........	205,006	19,502
1915..........	69,487	8,223
1916..........	131,481	15,814
1917..........	221,272	17,590
1918..........	86,482	20,708
1919..........	86,000	25,295
1920..........	40,188	11,065
1921..........	89,844	35,558
1922..........	92,688	55,486

Ounces; not stated after 1922.

Clay, common blue & gross almerode glass-pot clay, unwrought

1913..........	23,213	$211,005
1914..........	20,587	180,524
1915..........	12,274	107,146
1916..........	3,488	16,088
1917..........	412	2,353
1918..........	64	869
1919..........	80	493
1920..........	2,456	62,507
1921..........	4,564	98,029
1922..........	708	15,376

Tons.

Clays or earths, crude, n.s.p.f.

1913..........	37,370	$167,614
1914..........	37,572	210,574
1915..........	36,072	153,041
1916..........	34,677	148,916
1917..........	30,942	138,171
1918..........	24,474	144,666
1919	23,199	199,332
1920..........	23,324	200,868
1921..........	41,259	396,303
1922	30,024	273,257

Tons.

Coal tar, crude, & pitch

1913..........	14,093	$23,691
1914..........	17,515	25,140
1915..........	16,391	23,874
1916..........	19,206	32,635
1917..........	5,594	10,702

Barrels; stated separately after Sept. 8, 1916.

Coal tar, crude

1917..........	5,864	$10,381
1918..........	10,031	15,603
1919..........	25,400	42,270
1920	14,439	28,882
1921.	29,694	43,318
1922	29,072	57,286

Barrels.

Coal tar, pitch

1917..........	7,258	$ 8,146
1918..........	15,838	32,582
1919..........	3,293	7,093
1920..........	6,168	15,425
1921..........	6,271	20,060
1922	24	158

Barrels.

Cobalt, cobalt ore, & zaffer

1913..........	310,951	$ 30,713
1914..........	197,009	115,038
1915..........	24,095	8,225
1916..........	144,170	186,124
1917..........	136,883	191,966
1918..........	161,695	306,310

Stated separately after 1918.

Cobalt metal

1919..........	156,372	$511,683
1920..........	99,595	228,891
1921..........	133,857	322,293
1922..........	4,252	11,143

Cobalt ore

1919	220,125	$55,197
1920	17,035	2,823
1921	13,039	4,794
1922	7,657	3,235

Cobalt oxide, *see* Vol. III, Appendix XXVII

Cocaine & salts, & ecgonine

1913	3,715	$ 4,835
1914	3,291	4,101
1915	179	422
1916	4,275	5,887
1917	19,388	38,627
1918	8,597	35,358
1919	19,382	68,584
1920	11,614	29,217
1921	6,172	22,521
1922	7,376	16,064

No imports allowed after 1922.

Copper sulfate (blue vitriol)

1913	11,051	$ 728
1914	114,730	5,486
1915	45,239	2,156
1916	184,182	17,651
1917	15,952	2,233
1918	98,143	9,035
1919	120	36
1920	72,605	7,243
1921	676,628	38,370
1922	529,557	23,412

Copperas, *see* Ferrous sulfate

Corrosive sublimate

1920	3,306	$2,258
1921	665	683
1922	—	—

Cream of tartar, *see* Vol. III, Appendix X

Creosote, *see* Oil, creosote

Cresols, meta-, ortho-, para-

1918	20,708	$1,404
1919	11,200	1,221
1920	2,240	2,055
1921	204	175
1922	3,290	518
1923	13,714	7,361

Cryolite (Kryolith)

1913	2,519	$ 52,440
1914	2,157	47,435
1915	4,569	91,417
1916	3,962	84,497
1917	3,835	163,475
1918	4,383	$218,600
1919	19,951	97,500
1920	2,130	106,500
1921	3,866	194,158
1922	3,477	296,888

Tons.

Dextrin & substitutes, & burnt, soluble, or chemically treated starch

1914	471,491	$18,180
1915	274,668	12,028
1916	154,882	10,049
1917	32,773	2,855
1918	505	50
1919	—	—
1920	77,238	6,764
1921	238,767	13,954
1922	302,022	15,932

Dextrin from potato starch or flour

1914	5,226,421	$162,688
1915	4,595,949	154,337
1916	720,106	40,553
1917	210,948	17,882
1918	99,228	9,116
1919	421,971	39,533
1920	681,224	59,337
1921	566,670	35,824
1922	1,367,844	80,858

Dimethylaniline & dianisidine

1921	8,188,532	$165,639
1922	23,565	3,828

Divi-divi

1913	314,491	$ 4,143
1914	29,032	461
1915	4,513,219	71,367
1916	16,467,455	310,572
1917	15,969,144	293,191
1918	15,739,331	274,891
1919	26,556,867	522,913
1920	26,632,840	580,972
1921	7,558,995	91,405
1922	11,153,869	145,125

Dyeing materials, crude, n.e.s.

1913	155	$ 1,794
1914	371	6,097
1915	1,530	20,674
1916	7,043	172,765
1917	6,745	48,211
1918	16,489	425,942
1919	2,153	52,196
1920	2,339	49,913
1921	2,342	51,082
1922	4,731	118,406

Tons.

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Ethanol, *see* Alcohol, ethyl

Ethers, up to 10% alcohol, n.e.s.

1921..........	269	$ 796
1922..........	2,177	1,068

Ethers, over 10% alcohol, n.e.s.

1914..........	—	$1,868
1915..........	66	64
1916..........	140	169
1917..........	—	—
1918..........	880	182
1919..........	—	—
1920..........	—	—
1921..........	240	274
1922..........	1,316	1,319

Ethyl acetate

1920..........	400	$493
1921..........	—	—
1922..........	230	284

Ethyl chloride

1913..........	11,241	$ 7,903
1914..........	9,014	10,046
1915..........	—	—
1916..........	2,780	5,193
1917..........	8,917	5,207
1918..........	1,274	2,411
1919..........	22,495	2,250
1920..........	877	685
1921..........	7,009	6,482
1922..........	13,150	2,757

Ethyl ether

1913..........	755	$ 120
1914..........	915	131
1915..........	849	189
1916..........	62	23
1917..........	—	—
1918..........	8	7
1919..........	282,576	28,258
1920..........	100	34
1921..........	—	—
1922..........	988	384

Explosives, coal-tar

1913..........	85,068	$ 18,339
1914..........	—	—
1915..........	20,091	4,278
1916..........	—	—
1917..........	—	—
1918..........	—	—
1919..........	3,240,500	254,385

Ferromanganese

1919..........	24,006	$4,120,794
1920..........	38,973	3,980,743
1921..........	43,198	6,057,802
1922..........	31,164	1,877,094

Tons.

Ferrophosphorus

1913	81	$3,689
1914..........	26	1,136
1915..........	27	1,213
1916..........	12	617
1917..........	85	5,458
1918..........	10	1,055
1919	109,141	3,639
1920..........	61,665	2,207
1921..........	14,000	780
1922..........	11,997	132

In tons prior to 1919.

Ferrosilicon

1919..........	6,091	$521,142
1920	17,855	891,108
1921..........	7,361	397,991
1922.	10,977	524,355

Tons.

Ferrovanadium

1920..........	19,189	$39,254

Ferrous sulfate (copperas)

1913..........	6,196	$ 174
1914..........	1,120	18
1915..........	4,750	95
1916..........	—	—
1917..........	—	—
1918..........	—	—
1919..........	—	—
1920..........	377,613	4,869
1921..........	119,947	1,733
1922..........	240,517	2,022

Fertilizers, n.s.p.f.

1913..........	115,257	$2,190,816
1914..........	197,165	4,241,285
1915..........	100,155	2,208,193
1916..........	73,252	1,591,517
1917..........	71,374	1,521,307
1918..........	63,815	1,772,684
1919..........	55,775	2,260,253
1920..........	123,287	4,752,048
1921..........	113,353	5,434,425
1922..........	89,667	2,396,817

Tons.

Filter masse or filter stock

1914..........	486,476	$53,974
1915..........	349,498	41,880
1916..........	54,349	8,356
1917..........	65,052	10,304
1918..........	48,210	13,917
1919..........	6,605	1,097
1920..........	65,750	9,048
1921..........	146,282	26,455
1922..........	109,089	11,792

Flavoring extracts

1918..........	4,938	$ 6,383
1919..........	3,431	11,293
1920..........	5,057	9,173
1921..........	43,625	30,693
1922..........	671,523	409,930
1923..........	772,164	387,240

Floral essences & concretes

1914..........	—	$ 87,086
1915..........	—	145,973
1916..........	—	265,956
1917..........	—	408,936
1918..........	—	250,531
1919..........	—	34,610
1920..........	—	174,097
1921..........	—	176,198
1922..........	—	185,859

Fluospar

1913..........	23,786	$ 77,535
1914	13,663	50,943
1915	6,925	27,951
1916..........	8,808	32,482
1917..........	12,008	87,380
1918..........	10,936	117,279
1919..........	10,367	169,605
1920..........	11,312	146,151
1921..........	18,068	219,557
1922	8,661	86,678

Tons.

Formaldehyde solution

1914..........	14,228	$ 1,443
1915..........	7,700	814
1916..........	79,857	8,054
1917..........	23,935	2,349
1918..........	223,402	40,691
1919..........	162	71
1920..........	195,878	92,944
1921..........	274,000	125,819
1922..........	45,594	8,246

Fuller's earth, *see* Vol. II, Appendix XLIII

Fusel oil, *see* Vol. III, Appendix XXXV

Fustic

1913..........	3,785	$ 53,303
1914..........	7,121	100,501
1915..........	12,354	179,959
1916..........	17,469	289,913
1917..........	5,195	142,431
1918..........	16,259	435,428
1919..........	4,486	83,096
1920..........	929	16,567
1921..........	2,504	36,683
1922..........	4,390	85,912

Gas liquor, ammoniacal

1913..........	—	$35,245
1914..........	—	29,336
1915.........	—	31,466
1916..........	—	26,733
1917..........	—	23,335
1918.	—	5,059
1919..........	—	—
1920..........	—	18,672
1921..........	—	7,571
1922..........	—	35,156

Gasoline, *see* Oil, mineral

Glauber's salt, *see* Sodium sulfate, crystalline

Glazes, fluxes, enamels, & colors (ceramic & glass)

1914	—	$38,527
1915..........	—	70,782
1916	—	64,138
1917	—	43,421
1918	—	26,583
1919..........	19,046	22,839
1920..........	45,661	48,090
1921..........	53,907	60,753
1922..........	52,627	47,835

Glucose

1913..........	212,635	$7,166
1914..........	262,223	9,025
1915..........	52,799	1,880
1916..........	1,233	313
1917..........	7,696	331
1918..........	105,551	6,482
1919..........	400	40
1920..........	40,267	3,040
1921..........	50	5
1922..........	3,631	142

Not stated after 1922.

Glycerin, crude

1913..........	34,399,129	$4,247,032
1914..........	36,230,383	4,473,178
1915..........	18,661,929	2,185,368
1916..........	10,875,058	2,209,610

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Glycerin, crude (*Cont.*)

1917	4,078,803	$1,260,454
1918	1,925,815	830,145
1919	1,163,952	368,680
1920	15,664,109	1,849,998
1921	11,056,067	1,576,018
1922	2,091,117	287,148

Glycerin, refined

1913	432,339	$ 73,336
1914	551,306	90,562
1915	360,567	60,908
1916	303,463	132,469
1917	137,128	76,361
1918	19,750	17,438
1919	162,916	67,597
1920	1,911,278	414,316
1921	3,960,671	850,834
1922	75.953	16,649

Grease, enfleurage

1913	92,446	$124,195
1914	40,638	51,417
1915	28,407	31,578
1916	5,245	8,524
1917	26,636	33,945
1918	23,620	167,861
1919	13,357	196,345
1920	9,720	48,979
1921	19,726	241,958
1922	17,268	228,557

Guaiacol & derivatives

1914	1,637	$ 2,645
1915	6,907	11,125
1916	469	1,160
1917	200	6,458
1918	9,492	74,818
1919	2,063	40,407
1920	2,870	18,479
1921	3,465	12,951
1922	3,203	8,249

Guano

1913	16,462	$ 313,891
1914	21,853	754,727
1915	20,950	534,371
1916	15,732	425,210
1917	3,563	73,394
1918	10,663	308,268
1919	8,218	293,425
1920	18,796	1,550,098
1921	37,578	3,158,064
1922	1,305	48,675

Tons.

Gum, rosin, *see* Rosin

Hemlock bark extract

1915	5,263,296	$173,998
1916	5,577,989	390,287
1917	—	—
1918	—	—
1919	—	—
1920	—	—
1921	117,113	4,712
1922	320,569	12,194

Ichthyol

1913	44,347	$ 61,796
1914	66,957	92,485
1915	51,847	70,664
1916	69,227	59,470
1917	91,884	60,757
1918	65,982	43,541
1919	19,623	9,830
1920	98,870	91,927
1921	54,309	31,616
1922	107,119	140,314

Indigo, carmined

1912	9,047	$5,903
1913	16,329	9,986
1914	2,130	1,333

Not stated after Oct. 3, 1913.

Indigo, crude (natural, synthetic)

1913	7,712,488	$1,102,893
1914	8,252,528	1,115,128
1915	7,983,112	1,604,767
1916	6,794,518	8,451,501

Stated separately after Sept. 8, 1916.

Indigo, natural

1917	1,231,986	$2,449,361
1918	2,141,382	3,261,978
1919	794,251	961,610
1920	154,843	206,119
1921	61,967	121,820
1922	36,007	76,176

Indigo, synthetic

1917	886,700	$559,156
1918	942,946	553,246
1919	358,867	197,176
1920	520,347	351,440
1921	99,809	107,084
1922	101,683	157,925

Indigo dyes

1914	—	$ 34,342
1915	—	76,258
1916	—	155,254
1917	—	147,744

Stated as Indigoids, etc., after 1917.

Indigo extracts or pastes

1912	223,687	$45,984
1913	242,998	43,417
1914	11,998	2,540

Not stated after Oct. 3, 1913.

Indigoids from indigo, etc.

1918	13,037	$ 40,984
1919	4,236	9,378
1920	70,461	177,736
1921	67,269	110,596
1922	187,156	228,822
1923	64,399	111,270

Iodine, *see* Vol. III, Appendix LVIII

Iodoform

1913	16	$ 57
1914	86½	301
1915	10	40
1916	—	—
1917	—	—
1918	1	4
1919	—	—
1920	—	—
1921	7	27
1922	—	—

Iridium

1913	5,341	$348,333
1914	2,185	154,842
1915	3,801	220,823
1916	2,496	146,055
1917	3,899	355,206
1918	2,815	307,954
1919	3,678	503,047
1920	4,969	846,462
1921	3,282	641,349
1922	789	74,188

Troy ounces.

Kainite

1913	366,184	$2,149,689
1914	526,112	2,579,619
1915	79,124	444,996
1916	64	1,795
1917	—	—
1918	—	—
1919	—	—
1920	272,048	5,599,980
1921	204,834	4,782,974
1922	83,571	585,338

Kaolin, *see* China clay

Lac dye

1913	—	—
1914	—	—
1915	—	—
1916	86,600	$13,804
1917	—	—
1918	—	—
1919	—	—
1920	398,028	54,849
1921	680	135
1922	—	—

Not stated after 1922.

Lakes, dry or pulp, n.s.p.f.

1914	—	$ 59,603
1915	—	153,430
1916	—	29,839
1917	—	11,230
1918	—	8,301
1919	600	1,307
1920	8,901	7,870
1921	9,798	6,533
1922	169,895	9,234

Lead acetate, brown, gray, or yellow

1913	42	$ 8
1914	17,477	957
1915	—	—
1916	124	17
1917	225	97
1918	—	—
1919	—	—
1920	—	—
1921	3,854	306
1922	5,123	346

Lead acetate, white

1913	21,599	$ 1,177
1914	110,936	10,768
1915	31,096	1,809
1916	—	—
1917	—	—
1918	—	—
1919	220	212
1920	14	7
1921	6,361	549
1922	83,712	6,378

Lead carbonate, basic, *see* Vol. III, Appendix XXIII

Lead nitrate

1913	11,305	$605
1914	11,312	712
1915	—	—
1916	2,205	280
1917	224	22
1918	—	—
1919	—	—
1920	—	—
1921	—	—
1922	7,746	530

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Lead compounds, n.e.s.

1914..........	102,899	$9,348
1915..........	86,514	7,471
1916..........	39,823	3,644
1917..........	32,887	3,069
1918..........	4,510	242
1919..........	2,408	321
1920..........	5,591	958
1921..........	13,224	2,102
1922..........	3,481	683

Lead pigments, n.e.s.

1921..........	35,227	$2,869
1922..........	1,489	467

Lime, n.e.s.

1913..........	77,319	$ 42,839
1914..........	65,036	42,926
1915..........	66,634	29,518
1916..........	92,321	42,537
1917..........	160,776	74,437
1918..........	147,080	77,733
1919..........	167,152	103,749
1920..........	278,046	219,986
1921..........	361,553	357,992
1922..........	224,189	241,580

Hundredweight; including hydrated lime.

Lime, chlorinated (bleaching powder)

1913..........	76,092,327	$619,492
1914..........	48,497,239	416,893
1915..........	18,402,130	197,975
1916..........	3,289,790	80,418
1917..........	65,564	3,888
1918..........	535	83
1919..........	539,596	11,363
1920..........	830,007	13,611
1921..........	4,584,344	144,029
1922..........	17,374,617	267,065

Lime citrate

1913..........	5,526,954	$ 756,309
1914..........	3,119,924	496,517
1915..........	6,242,244	1,102,629
1916..........	8,127,364	1,763,652
1917..........	6,361,458	1,554,577
1918..........	4,013,606	814,073
1919..........	2,773,095	1,136,057
1920..........	10,929,314	2,908,023
1921..........	5,060,407	1,104,576
1922..........	8,983,134	1,194,964

Litharge, *see* Vol. III, Appendix XXIII

Lithopone, *see* Vol. III, Appendix XXV

Litmus

1913..........	—	$ 216
1914..........	—	263
1915..........	—	59
1916..........	—	280
1917..........	—	648
1918..........	—	44
1919..........	5,016	4,177
1920..........	2,054	1,535
1921..........	5,303	3,419
1922..........	2,396	1,756

Logwood

1913..........	36,952	$ 475,484
1914..........	30,172	379,754
1915..........	54,704	722,410
1916..........	134,819	3,437,388
1917..........	121,762	4,127,031
1918..........	55,354	1,175,049
1919..........	20,871	412,952
1920..........	45,073	1,144,455
1921..........	56,977	1,697,436
1922..........	31,418	644,812

Tons.

Logwood extract

1913..........	2,258,206	$111,575
1914..........	1,228,178	77,119
1915..........	2,061,368	144,207
1916..........	2,652,787	316,872
1917..........	1,147,448	164,711
1918..........	215,954	24,698
1919..........	265,774	51,041
1920..........	868,297	70,910
1921..........	116,185	25,500
1922..........	1,317,694	78,601

Magnesia, calcined or oxide

1913..........	72,579	$12,592
1914..........	109,396	15,118
1915..........	145,806	16,012
1916..........	46,008	7,560
1917..........	56,656	17,575
1918..........	12,165	4,483
1919..........	572	1,318
1920..........	38,391	15,063
1921..........	17,664	6,909
1922..........	60,998	10,474

Magnesite, caustic, calcined

1913..........	345,322,155	$1,731,443
1914..........	288,989,577	1,485,273
1915..........	125,893,407	751,766
1916..........	32,372,610	282,768
1917..........	9,448,817	182,037
1918..........	22,764,029	535,202

1919..........	12,058	$532,020
1920..........	13,619	365,623
1921..........	9,425	336,539
1922..........	16,340	442,259

After 1918, in tons.

Magnesite, crude

1913..........	33,654,260	$111,276
1914..........	21,590,605	46,611
1915..........	37,463,509	80,625
1916..........	101,591,459	281,951
1917..........	179,292,638	748,951
1918..........	18,552,767	104,947
1919..........	1,975	57,434
1920..........	13,881	232,708
1921..........	50,927	450,872
1922..........	60,372	907,827

After 1918, in tons.

Magnesium, metal & scrap

1920..........	17,988	$19,492
1921..........	43,297	34,123
1922..........	70,186	32,800

Magnesium carbonate, precipitated

1913..........	77,190	$3,811
1914..........	58,683	3,972
1915..........	49,731	2,554
1916..........	19,888	1,414
1917..........	25,092	5,077
1918..........	5,681	1,906
1919..........	232	131
1920..........	19,112	2,311
1921	3,760	666
1922..........	26,888	2,998

Magnesium chloride, anhydrous

1919	18,676	$ 1,907
1920..........	214,107	3,371
1921..........	2,022,339	25,535
1922..........	9,011,216	102,464

Magnesium sulfate (Epsom salt)

1913..........	9,345,099	$ 35,739
1914..........	13,550,599	48,742
1915..........	7,005,598	32,862
1916..........	1,456,254	8,503
1917..........	54,200	875
1918..........	48,540	915
1919..........	4,350	167
1920..........	662,896	8,925
1921..........	6,591,977	105,776
1922..........	16,180,525	119,951

Mangrove bark

1913..........	17,578	$374,506
1914..........	7,743	191,472
1915..........	8,326	222,066
1916..........	21,107	581,190
1917..........	10,565	$297,897
1918..........	3,529	72,956
1919..........	2,817	125,603
1920..........	2,544	109,085
1921..........	7,156	344,413
1922..........	1,668	40,857

Manure salts, double manure salts, & hard salts

1913..........	172,557	$1,798,773
1914..........	260,977	2,757,013
1915..........	66,411	757,151
1916..........	2,278	42,368
1917..........	324	7,794
1918..........	225	9,047
1919..........	—	—
1920..........	240,899	8,215,063
1921..........	123,273	4,165,817
1922..........	81,442	957,443

Tons.

Menthol

1913..........	49,896	$ 289,058
1914..........	127,924	408,954
1915..........	111,020	236,759
1916..........	145,203	300,589
1917..........	172,767	398,191
1918..........	172,450	446,386
1919..........	243,743	1,055,920
1920..........	181,160	1,208,908
1921..........	239,297	1,575,824
1922..........	162,263	770,694

Mercurial medicinal preparations, n.e.s.

1921	6,769	$8,149
1922	1,967	1,424
1923..........	1,935	3,520

Mercury, *see* Vol. III, Appendix LVII

Methyl alcohol

1913..........	362	$ 387
1914..........	109,022	42,598
1915..........	39,485	11,880
1916..........	46,829	9,496
1917..........	11,267	4,502
1918..........	205,276	202,994
1919..........	4,375	11,141
1920..........	566	1,956
1921..........	214,328	525,730
1922..........	20	31

Gallons.

Mineral salts, from mineral waters

1913..........	103,337	$35,420
1914..........	82,569	40,840
1915..........	10,757	9,642
1916..........	425	213
1917..........	626	313

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Mineral salts, from mineral waters (*Cont.*)

1918..........	4,699,735	$14,230
1919..........	1,414,450	10,237
1920..........	753,859	10,946
1921..........	97,708	13,814
1922..........	608,540	13,379

Monazite sand & other thorium ores

1913..........	1,145,010	$ 94,425
1914..........	170,792	12,984
1915..........	1,493,028	133,819
1916..........	2,468,146	191,576
1917..........	4,020,023	263,331
1918..........	4,961,385	332,383
1919..........	952,304	55,898
1920..........	1,148,447	99,672
1921..........	1,036,420	71,745
1922..........	101,550	7,978

Morphine sulfate

1913..........	24,797	$141,221
1914..........	5,805	14,220
1915..........	1,383	3,300
1916..........	2,685	8,906
1917..........	5,584	22,675
1918..........	25,115	202,263
1919..........	25,370	158,307
1920..........	7,460	32,111
1921..........	1,550	4,594
1922..........	3,460	6,406
1923..........	200	361

Ounces; no imports allowed after 1923.

Myrobalans fruit

1913..........	19,735,724	$195,264
1914..........	24,256,373	438,672
1915..........	18,417,434	198,347
1916..........	25,612,765	375,401
1917..........	16,087,463	421,824
1918..........	4,408,522	110,444
1919..........	9,597,836	188,517
1920..........	62,196,177	993,932
1921..........	28,077,222	372,205
1922..........	28,567,166	194,465

Naphtha, *see* Oil, mineral

Naphthalene, solidifying under 79° C.

1918..........	3,579,187	$146,655
1919..........	3,591,108	109,381
1920..........	6,113,768	165,383
1921..........	13,925,789	515,078
1922..........	2,344,951	52,496

Naphthalene, solidifying at 79° C. or above

1918..........	92,888	$4,998
1919..........	60	10
1920..........	161,871	8,076
1921..........	3,974,776	$439,233
1922..........	53,496	5,453

Naphthol, alpha & beta (non-medicinal)

1921..........	54,341	$64,248
1922..........	279,623	49,353

Naphthol, beta, & benzaldehyde (medicinal)

1919..........	955	$ 716
1920..........	32,996	23,002
1921..........	2	4
1922..........	1,056	465

Naphthylamine & naphthylenediamine

1918..........	11,761	$5,895
1919..........	—	—
1920..........	—	—
1921..........	69,695	7,208
1922..........	—	—

Naval stores, *see* Rosin; Turpentine

Nickel, ore, oxide, etc., *see* Vol. III, Appendix XXII

Nitrobenzene

1920..........	43,623	$7,222
1921..........	23,781	2,790

Not stated after 1922.

Nutgall extract

1913..........	145,919	$18,228
1914	205,130	25,017
1915..........	157,084	23,262
1916..........	61,055	11,444
1917..........	45,760	9,867
1918..........	36,475	12,761
1919..........	34,033	12,508
1920..........	48,654	26,565
1921..........	4,219	1,114
1922	32,458	5,192
1923..........	150,505	28,455

Nutgalls & gall nuts

1913..........	—	$126,435
1914..........	—	177,788
1915..........	—	137,972
1916..........	—	420,030
1917..........	—	214,653
1918..........	—	872,173
1919..........	1,760,746	362,975
1920..........	2,776,978	647,268
1921..........	2,248,951	532,070
1922..........	565,508	75,496

Ochers, crude

1913..........	17,583,272	$162,387
1914..........	21,641,976	154,547
1915..........	17,430,128	124,359

1916..........	18,049,375	$153,880
1917..........	17,873,109	213,272
1918..........	7,087,557	131,055
1919..........	13,577,765	341,701
1920..........	13,264,966	229,526
1921..........	25,172,178	324,496
1922..........	11,856,246	198,701

Oil, Chinawood, China nut, or tung

1913..........	6,004,045	$ 2,738,000
1914..........	4,878,764	1,960,426
1915..........	4,723,584	1,649,270
1916..........	4,968,262	1,977,823
1917..........	6,846,631	4,046,132
1918..........	4,818,740	4,038,072
1919..........	6,218,557	7,248,054
1920..........	10,613,638	12,736,431
1921..........	4,439,975	4,817,082
1922..........	7,409,572	5,141,969

Gallons.

Oil, creosote

1913..........	63,997,602	$3,711,328
1914..........	59,271,677	3,822,919
1915..........	37,352,340	2,541,845
1916..........	40,496,987	3,206,780
1917..........	29,066,915	2,183,859
1918..........	3,857,869	329,846
1919..........	9,094,960	1,096,319
1920..........	8,338,761	1,171,717
1921..........	27,779,736	5,887,340
1922..........	39,143,044	3,965,786

Gallons.

Oil, fusel, *see* Vol. III, Appendix XXXV

Oil, mineral, crude (petroleum)

1913..........	450,542,222	$ 7,608,796
1914..........	843,080,788	11,779,938
1915..........	653,757,824	8,918,138
1916..........	859,736,962	12,226,179
1917..........	1,036,417,009	14,181,349
1918..........	1,348,419,493	18,239,207
1919..........	1,929,339,105	24,166,677
1920..........	2,824,332,765	33,791,375
1921..........	5,609,224,120	71,030,595
1922..........	4,710,620,838	72,960,648

Gallons.

Oil, mineral, lubricating (including paraffin oil)

1913..........	116,192	$ 35,193
1914..........	167,384	55,923
1915..........	60,412	11,609
1916..........	774,250	149,625
1917..........	409,746	40,710
1918..........	24,628	7,502
1919..........	551,142	75,451
1920..........	819,111	161,792
1921..........	4,344	$ 3,792
1922..........	429,361	53,744

Gallons.

Oil, mineral, refined (benzine)

1913..........	14,162,423	$1,266,896
1914..........	16,152,167	1,399,630
1915..........	6,783,627	727,855
1916..........	5,100	2,150

Gallons; not stated after 1916.

Oil, mineral, refined (benzine, gasoline, & naphtha)

1917..........	10,744,592	$1,396,101
1918..........	11,069,898	1,473,027
1919..........	11,760,856	1,867,863
1920..........	25 637,592	3,147,635
1921..........	31,778,815	3,711,948
1922..........	69,319,919	5,607,943
1923..........	87,801,664	7,176,506

Gallons.

Oil, mineral, refined (gasoline & naphtha)

1913..........	570	$ 118
1914..........	14,175	1,992
1915..........	1,136,797	34,701
1916..........	2,638	458

Gallons.

Oil, mineral, refined (all other)

1913..........	1,464,412	$ 307,479
1914..........	1,796,093	430,664
1915..........	496,968	98,696
1916	1,727,683	134,815
1917	32,259,588	2,221,816
1918	43,927,718	2,406,764
1919..........	37,299,989	2,585,007
1920	59,040,338	3,945,468
1921	97,728,455	7,138,962
1922..........	112,073,487	7,179,162
1923..........	589,175,634	13,928,891

Gallons.

Oleostearin

1913..........	9,540,347	$ 967,000
1914..........	5,679,535	497,973
1915..........	2,644,460	226,661
1916..........	910,478	81,280
1917..........	1,113,277	114,640
1918..........	6,575,379	1,118,413
1919..........	1,601,574	314,308
1920..........	1,307,847	274,545
1921..........	842,908	92,279
1922..........	378,222	32,596

Opium, alkaloids, salts, esters, n.e.s.

1913..........	9,672	$28,587
1914..........	11,593	64,528

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Opium, alkaloids, salts, esters, n.e.s. (*Cont.*)

1915..........	8,626	$ 49,584
1916..........	2,360	9,981
1917..........	34,179	165,028
1918..........	20,479	126,882
1919..........	56,895	318,361
1920..........	28,793	155,979
1921..........	573	1,315
1922..........	4,625	17,646
1923..........	200	981

Ounces; no imports allowed after 1923.

Orange mineral, *see* Vol. III, Appendix XXIII

Orchil & liquid

1913..........	—	$ 27,386
1914..........	—	21,569
1915..........	—	37,802
1916..........	—	114,603
1917..........	—	98,905
1918..........	—	55,612
1919..........	259,124	30,651
1920..........	634,570	63,380
1921..........	520,275	77,409
1922..........	424,398	56,030

Osmiridium

1914..........	666	$ 43,659
1915..........	911	58,014
1916..........	302	9,654
1917..........	333	24,293
1918..........	158	16,015
1919..........	809	77,347
1920..........	2,814	302,070
1921..........	3,619	365,245
1922..........	2,735	273,401

Troy ounces.

Osmium

1919..........	1,957	$119,328
1920..........	624	29,021
1921..........	351	23,275
1922..........	608	46,158

Troy ounces.

Palladium

1914..........	3,986	$169,171
1915..........	40	2,779
1916..........	8,011	304,559
1917..........	1,663	95,331
1918..........	1,317	148,938
1919..........	2,020	77,642
1920..........	6,518	599,471
1921..........	5,817	424,472
1922..........	12,165	639,976

Troy ounces.

Paraffin & wax (excluding oil)

1913..........	11,521,205	$503,802
1914..........	7,501,463	327,402
1915..........	5,628,811	254,389
1916..........	8,526,929	418,362
1917..........	10,641,404	654,186
1918..........	8,881,023	656,474
1919..........	6,600,404	754,351
1920..........	8,687,728	820,299
1921..........	5,714,653	630,575
1922..........	5,654,930	230,862

Paris green & London purple

1913..........	165,820	$7,692
1914..........	33,373	3,572
1915..........	16,800	2,975
1916..........	31,917	8,163
1917..........	—	—
1918	48	189
1919	18	14
1920..........	—	—
1921..........	992	372
1922..........	1,787	316

Paris white, *see* Whiting

Perfumery, etc., with alcohol

1913..........	286,025	$ 819,685
1914..........	301,443	771,758
1915..........	240,075	689,930
1916..........	281,387	828,727
1917..........	359,200	1,085,369
1918..........	267,733	1,014,647
1919..........	221,041	911,014
1920..........	1,620,601	3,533,172
1921..........	1,774,025	3,639,951
1922..........	566,365	2,339,280

Petroleum, *see* Oil, mineral

Phenol, *see* Vol. II, Appendix XXIII

Phenolphthalein

1914..........	14,076	$14,090
1915..........	49,326	46,295
1916..........	11,432	9,740
1917..........	3,576	7,794
1918..........	—	—
1919..........	100	1,200
1920..........	200	726
1921..........	—	—
1922..........	5,120	2,421

Phenylenediamine, phenylglycine, etc.

1919..........	2,246	$1,225
1920..........	2,929	2,431

Phosphate materials, crude, n.e.s.

1914	23,551	$177,838
1915	2,601	26,982
1916	8,190	69,820
1917	96	1,420
1918	6	60
1919	32	323
1920	54	1,681
1921	541	9,725
1922	3,945	63,150

Tons.

Phosphate rock, *see* Vol. II, Appendix XXIX

Phosphorus

1914	605	$ 264
1915	612	251
1916	—	—
1917	4,010	2,306
1918	88,692	57,572
1919	564,043	205,507
1920	99,806	23,462
1921	361,332	70,644
1922	648,135	86,884

Photographic chemicals, coal-tar

1917	11,322	$103,580
1918	11,492	80,963
1919	14,261	99,318
1920	15,477	72,109
1921	30,727	80,632
1922	11,650	25,917

Pitch, Burgundy

1913	977,629	$43,799
1914	1,055,327	40,480
1915	131,967	4,051
1916	14,756	673
1917	25	3
1918	100	12
1919	—	—
1920	—	—
1921	3,776	476
1922	47,191	6,532

Plumbago or graphite

1913	25,233	$1,972,177
1914	24,866	1,846,074
1915	17,057	1,387,873
1916	30,938	4,298,530
1917	42,270	9,678,160
1918	25,440	6,018,662
1919	18,670	2,222,519
1920	20,924	2,346,302
1921	14,797	1,160,054
1922	6,279	345,815
1923	15,936	543,567

Tons.

Potash, *see* Vol. II, Appendix XXIV

Potassium

1921	15,227	$ 581
1922	42,869	3,643

Potassium bicarbonate

1913	311,645	$ 14,295
1914	478,853	22,767
1915	383,534	20,341
1916	2,062	614
1917	171,528	84,381
1918	87,946	25,119
1919	5,008	1,200
1920	10,053	5,271
1921	594,287	116,495
1922	381,605	19,898

Potassium bitartrate, *see* Argols

Potassium carbonate, crude

1913	10,063,912	$ 295,066
1914	9,046,302	240,451
1915	8,620,504	291,341
1916	444,241	27,689
1917	1,069,408	185,910
1918	9,183,741	2,928,288
1919	1,092,792	373,745
1920	15,916,283	301,541
1921	3,515,339	369,699
1922	4,097,490	176,742

Potassium carbonate, refined

1913	14,035,111	$412,587
1914	10,421,005	368,958
1915	2,377,940	92,959
1916	174,587	38,604
1917	202,385	53,170
1918	445,282	124,019
1919	130,040	40,980
1920	1,318,531	144,407
1921	577,275	162,255
1922	266,527	16,455

Potassium chlorate & perchlorate

1913	1,235,732	$ 66,609
1914	40,319	3,408
1915	27,419	4,614
1916	—	—
1917	437,339	194,008
1918	1,029,980	610,702
1919	315,565	113,498
1920	698,385	87,205
1921	2,060,124	179,568
1922	8,806,221	327,539

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Potassium chloride (muriate), crude

1913	223,887	$ 6,737,757
1914	234,856	7,925,781
1915	102,882	3,660,353
1916	2,126	460,888
1917	606	174,806
1918	596	166,979
1919	1,677	201,307
1920	110,324	11,038,173
1921	49,911	5,290,196
1922	131,423	5,549,580

Tons.

Potassium chromate & bichromate, *see* Vol. III, Appendix XVI

Potassium cyanide

1913	950,890	$137,535
1914	1,236,799	183,259
1915	747,627	143,331
1916	43,705	9,311
1917	70,147	49,513
1918	13,455	3,150
1919	444,581	32,161
1920	5,175,608	430,873
1921	13,353,271	977,664
1922	2,007,752	175,019

Potassium ferricyanide (red prussiate)

1913	65,316	$11,302
1914	89,976	15,325
1915	83,574	14,922
1916	2,560	3,520
1917	4,523	10,425
1918	9,824	18,496
1919	13,992	25,497
1920	87,506	52,483
1921	66,004	30,232
1922	39,716	15,121

Potassium ferrocyanide (yellow prussiate)

1913	2,812,408	$309,302
1914	3,508,228	390,021
1915	2,316,736	255,711
1916	44,156	31,651
1917	41,128	32,251
1918	134,638	111,096
1919	58,003	45,869
1920	1,141,224	188,797
1921	398,961	99,211
1922	515,633	109,228

Potassium hydroxide, unrefined

1912	8,422,007	$330,684
1913	8,994,449	348,501
1914	8,565,451	326,650

After 1914, see below.

Potassium hydroxide, refined

1912	77,184	$ 8,097
1913	112,822	11,920
1914	18,751	1,977

After 1914, see below.

Potassium hydroxide (caustic)

1915	4,993,471	$225,002
1916	39,770	9,222
1917	74,780	33,648
1918	11,732	4,398
1919	466,620	124,563
1920	782,477	220,163
1921	4,934,697	474,479
1922	15,079,586	685,716

Potassium iodide

1913	120	$ 239
1914	270	491
1915	4	13
1916	309	1,032
1917	24,357	58,752
1918	65,992	133,611
1919	25,963	74,834
1920	11,377	34,766
1921	890	2,435
1922	—	—

Potassium nitrate, crude

1913	10,989,382	$ 288,995
1914	3,547,252	115,470
1915	677,785	22,483
1916	5,412,130	734,123
1917	10,171,654	904,506
1918	8,715,327	956,853
1919	34,557,048	1,298,391
1920	20,862,012	929,045
1921	30,868,786	1,407,044
1922	6,208,779	189,569

Potassium nitrate, refined

1913	197	$ 22,142
1914	166	20,173
1915	34	4,222
1916	2	749
1917	288	35,143
1918	43	16,193
1919	1	96
1920	103	20,658
1921	14,444	107,649
1922	683	48,558

Tons.

Potassium permanganate

1913	357,366	$25,314
1914	1,351,855	91,065
1915	1,039,304	78,924

1916	214,291	$ 57,309
1917	6,946	11,727
1918	43,826	106,104
1919	18,107	43,830
1920	9,446	5,100
1921	104,041	47,984
1922	856,067	109,085

Potassium sulfate, crude

1913	48,023	$1,798,369
1914	44,986	1,887,491
1915	21,705	1,071,623
1916	2,427	197,808
1917	656	20,538
1918	136	19,837
1919	137	23,304
1920	6,356	1,073,322
1921	12,081	1,660,798
1922	45,280	2,085,348

Tons.

Potassium & sodium tartrate, *see* Vol. III, Appendix X

Pyridine & quinoline

1918	11,981	$ 1,051
1919	123,049	15,248
1920	493,383	56,604
1921	434,668	121,437
1922	148,911	22,075
1923	363,762	92,398

Pyrites, *see* Vol. II, Appendix XXXII

Pyroxylin compounds & other cellulose esters

1913	—	$288,639
1914	—	583,391
1915	—	371,714
1916	—	127,627
1917	—	53,693
1918	—	53,054
1919	—	43,172
1920	—	77,673
1921	—	155,536
1922	—	36,069

Quebracho extract

1913	63,604,814	$1,672,314
1914	99,605,839	2,699,104
1915	125,565,857	3,676,749
1916	81,501,892	5,432,458
1917	61,977,849	5,382,433
1918	101,523,282	4,917,212
1919	137,151,143	5,856,803
1920	154,944,717	8,123,641
1921	110,184,308	6,602,449
1922	134,274,423	5,205,641

Quebracho wood

1913	101,869	$1,300,126
1914	73,957	900,880
1915	54,715	750,873
1916	106,864	1,598,465
1917	95,211	1,086,946
1918	53,871	848,671
1919	2,689	31,048
1920	33,672	480,503
1921	32,901	531,566
1922	23,987	265,910

Tons.

Quicksilver, *see* Vol. III, Appendix LVII

Quinine sulfate

1913	2,279,734	$ 397,409
1914	2 224,765	486,641
1915	1,508,931	378,511
1916	1,409,228	1,022,821
1917	623,947	324,438
1918	1,256,172	593,019
1919	2,101,006	1,238,125
1920	2,888,550	1,376,514
1921	1,935,531	1,489,166
1922	1,008,600	594,178

Ounces.

Radium salts

1914	—	$29,983
1915	—	29,983
1916	—	3,712
1917	—	50
1918	—	—
1919	11	892
1920	12	11,033
1921	807	3,027
1922	913	15,719

Grains.

Red lead, *see* Vol. III, Appendix XXIII

Resorcinol (medical)

1920	5,159	$ 2,642
1921	156,028	112,312
1922	—	—

Rochelle salt, *see* Vol. III, Appendix X

Rose leaves

1913	—	$ 67
1914	—	1,434
1915	—	484
1916	—	1,060
1917	—	4,199
1918	—	4,164
1919	1,399	557
1920	25,627	10,566
1921	9,536	4,153
1922	7,255	2,606

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Rosin, gum

1913	299,983	$ 12,605
1914	2,742,083	58,684
1915	1,505,790	42,085
1916	5,571,325	146,250
1917	129,848	3,380
1918	54,334	2,840
1919	251,853	11,064
1920	141,935	7,223
1921	1,903	126
1922	29,943	1,166

Saccharin

1913	47	$ 64
1914	8	30
1915	5,617	6,737
1916	12,954	76,789
1917	1,596	18,276
1918	1	48
1919	—	—
1920	—	—
1921	40	39
1922	46	118

Saffron, safflower, & saffron cake extract

1913	—	$ 93,146
1914	—	85,678
1915	—	70,132
1916	—	111,420
1917	—	124,235
1918	—	54,109
1919	16,459	77,273
1920	25,704	138,732
1921	22,969	67,454
1922	26,273	88,584

Sal ammoniac, *see* Ammonium chloride

Sal soda, *see* Soda, hydrated

Salicin

1913	3,274	$12,146
1914	4,129	14,982
1915	1,800	6,560
1916	453	2,135
1917	390	2,307
1918	319	2,845
1919	560	5,791
1920	1,374	16,379
1921	1,843	19,771
1922	2,000	7,770

Salol

1914	660	$ 219
1915	23,430	11,445
1916	4,069	2,182

Santonin & salts

1913	1,982	$ 44,358
1914	5,230	125,128
1915	912	25,558
1916	20,925	586,850
1917	111	3,966
1918	223	7,502
1919	1,125	49,688
1920	2,778	162,335
1921	2,613	236,864
1922	7,960	959,153

Selenium & salts

1914	—	$ 363
1915	—	43
1916	—	16
1917	—	302
1918	—	2,236
1919	—	—
1920	114	25,866
1921	1,104	2,092
1922	1,654	2,534

Sheep dip

1913	—	$63,527
1914	—	16,842
1915	—	32,963
1916	—	21,198
1917	—	17,185
1918	—	26,989
1919	88,335	6,958
1920	172,562	13,880
1921	53,450	5,240
1922	10,377	1,480

Siennas, crude

1914	6,489,329	$ 55,925
1915	6,656,031	64,658
1916	5,206,292	83,428
1917	2,990,972	61,163
1918	2,731,181	61,301
1919	2,060,857	48,237
1920	2,555,705	76,715
1921	5,111,832	150,857
1922	2,590,299	102,534

Slag, basic (fertilizer)

1913	5,124	$146,477
1914	9,509	108,565
1915	561	7,309
1916	81	1,031
1917	41	549
1918	2	54
1919	117	2,305
1920	22	689

1921..........	—	—
1922..........	33	$938

Tons.

Soda, caustic, *see* Sodium hydroxide

Soda, hydrated (sal soda)

1913..........	128,027	$1,010
1914..........	163,626	1,274
1915..........	104,800	606
1916..........	67,210	334
1917..........	50	4
1918..........	75	3
1919..........	44,800	1,156
1920..........	5,056	603
1921..........	45,360	1,390
1922..........	23,419	262

Soda ash (carbonate, calcined)

1913..........	3,100,790	$ 35,461
1914..........	2,228,991	28,100
1915..........	2,127,542	29,022
1916..........	878,175	20,718
1917..........	1,047,295	29,239
1918..........	1,514,765	55,231
1919..........	—	—
1920..........	1,926,332	39,437
1921..........	6,630,873	93,802
1922..........	17,944,667	242,688

Sodium

1920...........	5,600	$ 684
1921..........	—	—
1922..........	418,997	64,976

Sodium arsenate

1914..........	228,270	$ 8,267
1915..........	85,850	3,188
1916..........	36,176	3,436
1917..........	23,296	2,404
1918..........	35	88
1919..........	—	—
1920..........	11,448	1,118
1921..........	131,915	11,946
1922..........	14,146	1,122

Sodium benzoate

1914..........	190	$ 97
1915..........	40,903	19,183
1916..........	35,188	100,195
1917..........	80,755	339,868
1918..........	1,369	4,742
1919..........	55,188	11,459
1920..........	67,397	10,478
1921..........	1,032	10,122
1922..........	11,369	3,001

Sodium bicarbonate

1913..........	80,699	$2,238
1914..........	88,873	2,324
1915..........	93,318	2,584
1916..........	129,414	2,867
1917..........	34,742	1,821
1918..........	29,444	944
1919..........	12,665	711
1920..........	13,353	3,514
1921..........	5,960	417
1922..........	357,216	5,627

Sodium borate, *see* Borax, refined

Sodium carbonate, crystal

1913..........	169,174	$2,928
1914..........	307,488	3,323
1915..........	144,452	2,748
1916..........	49,231	889
1917..........	60,464	1,299
1918..........	70,116	2,028
1919..........	—	—
1920..........	203	16
1921..........	74,271	2,266
1922..........	16,042	623

Sodium chlorate

1913..........	50	$ 10
1914..........	469	84
1915..........	62	6
1916..........	22,176	3,105
1917..........	33,600	1,080
1918..........	44,800	8,064
1919..........	10	2
1920..........	424,280	38,973
1921..........	365,611	26,397
1922..........	1,031,351	46,910

Sodium chromate & bichromate, *see* Vol. III, Appendix XVI

Sodium cyanide

1914..........	7,856,611	$1,120,789
1915..........	6,187,418	955,907
1916..........	684,198	115,186
1917..........	1,875,824	861,777
1918..........	84,652	39,405
1919..........	138,970	13,406
1920..........	8,629,502	729,514
1921..........	7,733,063	1,074,434
1922..........	14,328,817	1,237,622

Sodium ferrocyanide (yellow prussiate)

1913..........	1,887,369	$118,475
1914..........	2,295,724	171,834
1915..........	1,529,958	120,477
1916..........	527,130	136,250

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Sodium ferrocyanide (yellow prussiate) (*Cont.*)

1917	175,980	$ 96,592
1918	—	—
1919	274,441	99,899
1920	2,633,090	445,849
1921	1,610,036	282,966
1922	3,832,491	473,065

Sodium hydrosulfite & compounds

1913	7,299	$ 228
1914	926,135	128,828
1915	1,855,223	268,693
1916	5,125	166
1917	1,836	1,193
1918	6,960	6,723
1919	27,616	6,112
1920	11,014	7,904
1921	6,160	4,085
1922	1,717,653	32,617

Sodium hydroxide (caustic)

1913	671,480	$25,364
1914	665,320	23,914
1915	444,185	19,318
1916	225,189	20,981
1917	109,983	21,052
1918	15,976	9,591
1919	2	2
1920	117,322	14,842
1921	67,950	7,766
1922	1,548,020	70,559

Sodium nitrate, *see* Vol. II, Appendix XIV

Sodium nitrite

1913	1,269,544	$ 57,595
1914	1,844,379	76,813
1915	1,696,567	74,263
1916	2,593,330	170,160
1917	3,675,179	261,555
1918	2,755,033	226,294
1919	1,746,976	159,355
1920	8,897,758	978,676
1921	6,721,107	791,611
1922	1,372,768	70,813

Sodium phosphate

1913	30	$ 14
1914	1,364,789	24,975
1915	485,300	7,765
1916	1,066	79
1917	1,561	521
1918	112	69
1919	—	—
1920	56	$ 22
1921	238,416	8,113
1922	1,968,739	57,345

Sodium silicate (water glass)

1913	1,032,113	$ 9,400
1914	1,046,569	10,881
1915	1,587,902	16,292
1916	1,567,617	18,694
1917	1,203,844	18,493
1918	707,583	12,734
1919	673,777	16,647
1920	754,923	19,479
1921	1,069,468	32,033
1922	315,902	10,135

Sodium sulfate, crude (salt cake)

1913	189	$4,771
1914	206	2,436
1915	189	3,566
1916	91	6,392
1917	216	4,122
1918	463	8,382
1919	28	168
1920	—	—
1921	152	2,855
1922	189	5,994

Tons.

Sodium sulfate, crystallized (Glauber's salt)

1913	240	$ 5,685
1914	228	5,557
1915	53	1,113
1916	1	33
1917	—	—
1918	—	—
1919	—	—
1920	1	36
1921	44	710
1922	7,102	80,710

Tons.

Sodium sulfide

1913	951,664	$ 13,068
1914	2,529,911	36,383
1915	1,263,366	18,228
1916	80,513	4,616
1917	344,617	7,214
1918	117,532	1,707
1919	314,887	10,494
1920	2,008,495	64,678
1921	741,965	40,440
1922	8,916,743	261,210

Sodium sulfite

1913..........	27,152	$ 400
1914..........	382,540	5,627
1915..........	165,594	4,316
1916..........	435	60
1917..........	68,224	1,221
1918..........	20,206	223
1919..........	11,400	1,007
1920..........	68,239	3,119
1921..........	206,423	8,369
1922..........	2,585,868	73,357

Spiegeleisen

1919..........	27	$ 1,018
1920..........	3,312	175,969
1921..........	2,127	109,140
1922..........	2,204	75,412

Strontium oxide

1913..........	—	$ 474
1914..........	—	1,969
1915..........	—	7,268
1916..........	—	8,311
1917..........	—	21,184
1918..........	—	6,873
1919..........	316,640	1,358
1920..........	1,050,347	6,230
1921..........	2,816,726	16,020
1922..........	—	—

Strychnine salts, n.e.s.

1913..........	966,575	$4,112,057
1914..........	846,905	3,753,879
1915..........	26,967	11,449
1916..........	59,278	37,652
1917..........	33,323	25,617
1918..........	9,688	9,726
1919..........	186	362
1920..........	18,448	32,901
1921..........	29,029	45,851
1922..........	106,902	133,271

Ounces.

Sulfur, refined

1913..........	1,742	$41,626
1914..........	1,523	39,634
1915..........	1,296	36,275
1916..........	850	26,778
1917..........	—	—
1918..........	—	—
1919..........	—	—
1920..........	50	2,512
1921..........	35	2,329
1922..........	—	—

Tons.

Sulfur, sublimed (flowers)

1913..........	6,104	$122,093
1914..........	599	15,841
1915..........	950	31,202
1916..........	200	7,512
1917..........	295	13,317
1918..........	—	—
1919..........	—	—
1920..........	—	—
1921..........	—	—
1922..........	98	4,004

Tons.

Sulfur, *see also* Vol. II, Appendix XXXIII

Sumac, ground

1913..........	14,112,112	$289,255
1914	9,678,719	231,580
1915..........	12,048,917	294,434
1916..........	20,411,022	527,102
1917..........	10,877,008	337,404
1918..........	10,557,920	355,192
1919..........	4,128,309	145,286
1920..........	16,636,562	593,739
1921.	2,245,615	62,786
1922..........	9,155,685	187,335

Sumac, unground

1913	621,366	$ 12,420
1914	1,335,566	32,238
1915..........	1,258,204	32,613
1916..........	1,131,369	28,164
1917..........	760,015	27,769
1918..........	3,619,439	141,063
1919..........	5,182,736	162,557
1920..........	4,543,852	161,497
1921..........	481,491	11,236
1922..........	3,461,640	81,175

Sumac extract

1913..........	1,270,825	$44,568
1914	1,463,297	59,022
1915..........	727,449	35,066
1916..........	36,003	4,108
1917..........	161,507	13,944
1918..........	23,706	2,616
1919..........	—	—
1920..........	—	—
1921..........	44,049	3,273
1922..........	37,262	3,875

Talc, *see* Vol. II, Appendix XLI

Tanning extract, oak

1921..........	1,484,032	$84,353
1922..........	496,679	27,557

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Tanning materials, crude, n.e.s.

1914..........	—	$ 81,595
1915..........	—	64,995
1916..........	—	270,292
1917..........	—	365,596
1918..........	—	95,446
1919..........	13,227,193	332,898
1920..........	49,008,222	1,092,589
1921..........	25,764,287	657,162
1922..........	9,214,918	136,184

Tar, coal, *see* Coal tar

Tar & pitch, wood

1914..........	561	$7,946
1915..........	129	1,551
1916..........	31	282
1917..........	631	5,903
1918..........	51	214
1919..........	132	215
1920..........	287	1,860
1921..........	712	3,677
1922..........	166	2,225

Barrels, 280 lb.

Terpin hydrate

1914..........	6,929	$1,020
1915..........	4,477	657

Thorium nitrate

1913..........	112,105	$212,263
1914..........	144,413	309,260
1915..........	78,516	186,385
1916..........	22,261	63,496
1917..........	1,877	5,263
1918..........	—	—
1919..........	—	—
1920..........	15,409	17,503
1921..........	59,903	103,788
1922..........	14,745	27,196

Thorium oxide & other salts

1914..........	2,465	$ 4,075
1915..........	82	359
1916..........	2,612	6,092
1917..........	1,616	3,984
1918..........	—	—
1919..........	28	124
1920..........	—	—
1921..........	—	—
1922..........	7,830	12,329

Thymol

1914..........	19,045	$24,765
1915..........	4,772	12,921
1916..........	443	1,973
1917..........	1,759	$ 13,741
1918..........	34,978	113,279
1919..........	8,430	75,013
1920..........	8,948	56,764
1921..........	9,593	63,326
1922..........	8,305	30,740

Tin (metal), *see* Vol. III, Appendix XXI

Tin ore, *see* Vol. III, Appendix XXI

Titanium

1921..........	2,315	$1,030
1922..........	13,686	3,334

Tumeric

1913..........	—	$ 33,735
1914..........	—	22,978
1915..........	—	10,145
1916..........	—	180,948
1917..........	—	112,372
1918..........	—	602
1919..........	689,962	46,205
1920..........	1,312,539	92,413
1921..........	737,736	37,136
1922..........	766,461	26,824

Turpentine, gum

1913..........	60,678	$ 9,169
1914..........	112,010	17,434
1915..........	20,904	3,172
1916..........	7,901	772
1917..........	1,045	248
1918..........	—	—
1919..........	—	—
1920..........	5,283	2,540
1921..........	10,914	2,626
1922..........	4,972	1,027

Turpentine, spirits

1913..........	56,457	$19,295
1914..........	72,679	28,818
1915..........	13,680	6,095
1916..........	20,675	8,252
1917..........	18,286	6,271
1918..........	1,433	564
1919..........	1,422	724
1920..........	28,506	37,555
1921..........	16,069	15,121
1922..........	70,467	45,184

Gallons.

Ultramarine, *see* Vol. III, Appendix XXVIII

Umbers, crude

1914..........	3,381,919	$25,798
1915..........	7,225,537	36,128
1916..........	8,914,389	55,076

1917	9,211,112	$66,217
1918	665,195	18,850
1919	425,017	11,770
1920	5,007,345	47,205
1921	7,124,483	77,526
1922	2,666,867	39,155

Uranium oxide & salts

1913	—	$21,435
1914	—	5,782
1915	—	1,969
1916	—	2,099
1917	—	3,018
1918	—	—
1919	1,154	1,309
1920	—	—
1921	441	468
1922	6,894	5,487

Urea

1914	17,981	$ 8,798
1915	65,464	31,994
1916	79,172	32,498
1917	56,429	36,248
1918	22,777	17,479
1919	11,576	7,693
1920	18,693	10,784
1921	7,714	5,349
1922	136,161	34,953

Valonia

1913	5,295,762	$ 79,610
1914	7,654,056	116,406
1915	6,352,190	88,061
1916	—	—
1917	—	—
1918	—	—
1919	150	5
1920	16,636,249	651,984
1921	11,723,598	331,443
1922	23,643,552	444,490

Valonia & myrobalans extract (tanning)

1919	2,037,349	$40,202
1920	2,058,075	59,765
1921	967,892	26,215
1922	1,663,783	35,654

Vanillin

1914	33,668	$ 6,446
1915	451	98
1916	—	—
1917	—	—
1918	—	—
1919	—	—
1920	71	94
1921	36,178	22,530
1922	10,510	4,240

Venetian red

1914	3,858,611	$33,077
1915	2,478,959	20,677
1916	1,687,616	12,947
1917	835,161	8,296
1918	433,638	5,135
1919	275,800	3,627
1920	278,673	4,524
1921	393,722	7,968
1922	72,519	2,246

Verdigris (copper acetate & subacetate)

1914	19,009	$ 2,530
1915	17,569	2,491
1916	81,005	15,648
1917	50,216	13,052
1918	26,837	8,694
1919	34,280	13,911
1920	8,809	2,122
1921	27,607	5,760
1922	19,569	3,478

Vermilion reds, with mercury

1914	72,881	$34,379
1915	95,659	58,697
1916	71,515	92,990
1917	17,557	24,170
1918	7,620	10,116
1919	9,556	17,439
1920	35,670	43,948
1921	22,203	22,868
1922	1,362	927

Wash blue, with ultramarine

1914	—	$12,906
1915	—	6,485
1916	—	4,907
1917	—	25,280
1918	—	15,686
1919	53,703	11,261
1920	134,812	22,955
1921	83,437	17,206
1922	50,835	7,266

White arsenic, *see* Vol. III, Appendix XXX

White lead, *see* Vol. III, Appendix XXIII

Whiting (Paris white)

1914	2,361,605	$ 10,453
1915	5,387,038	15,705
1916	3,655,123	14,459
1917	2,147,895	11,292
1918	4,908,295	31,033
1919	586,780	5,097
1920	3,639,237	28,610
1921	20,393,338	191,558
1922	22,391,035	114,784

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Witherite

1914..........	1,223,926	$ 7,927
1915..........	838,292	6,674
1916..........	1,714,414	20,446
1917..........	1,420,752	16,071
1918..........	1,194,268	20,146
1919..........	46,468	2,555
1920..........	1,195,824	22,465
1921..........	2,516,289	53,748
1922..........	2,692,290	41,589

Xylidine

1920..........	56,047	$41,237

Zinc chloride, *see* Vol. III, Appendix XX

Zinc dust

1913..........	5,615,766	$317,492
1914..........	4,788,433	223,775
1915..........	2,278,533	132,822
1916..........	1,365,705	255,192
1917..........	522,587	$83,010
1918..........	263,428	25,109
1919..........	24,982	1,637
1920..........	98,921	8,036
1921..........	13,023	2,287
1922..........	202,066	5,470

Zinc oxide, *see* Vol. III, Appendix XXIV

Zinc sulfate, *see* Vol. III, Appendix XX

Zinc sulfide

1913..........	5,163,642	$144,812
1914..........	1,338,999	42,130
1915..........	283,356	8,979
1916..........	96,402	7,368
1917..........	53,587	8,451
1918..........	7,098	4,535
1919..........	5,703	1,837
1920..........	15,271	5,475
1921..........	69,135	16,915
1922..........	73,334	5,977

Appendix IV

U. S. EXPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (pounds)

(From *O.P.D. Reptr. Ann. Rept. 1930.*)

Official data for fiscal years to June 30. Where figures missing, data unavailable because official records not kept. n.e.s. = not elsewhere specified; n.s.p.f. = not specially provided for.

Acid, carbolic

1918.........	8,688,554	$4,236,288
1919.........	5,810,314	2,173,171
1920.........	2,223,205	420,101
1921.........	659,890	86,297
1922.........	111,479	19,008

Acid, nitric, *see* Vol. III, Appendix IX

Acid, picric

1918.........	53,688,240	$33,902,957
1919.........	12,507,483	6,565,473
1920.........	8,073	3,430
1921.........	3,730	2,142
1922.........	466	288

Not stated after 1922.

Acid, sulfuric, *see* Vol. III, Appendix V

Acid phosphates, *see* Superphosphate

Acids & anhydrides, n.e.s.

1913	—	$ 364,347
1914.........	—	357,035
1915.........	—	2,611,741
1916.........	—	22,717,335
1917.........	—	54,725,124
1918.........	—	5,673,707
1919.........	—	4,573,969
1920.........	—	5,297,987
1921.........	—	3,029,332
1922.........	—	1,019,671

Alcohol, ethyl, pure & denatured

1913.........	151,232	$ 58,346
1914.........	187,845	67,728
1915.........	200,455	108,985
1916.........	24,433,243	8,784,742
1917.........	51,941,634	16,027,867
1918.........	8,351,142	4,619,878
1919.........	11,884,383	6,145,115

1920	27,376,167	$10,455,247
1921	14,635,394	7,569,381
1922	3,180,013	943,774

Gallons.

Alcohol, methyl, *see* Vol. III, Appendix XXXIII

Ammonium sulfate

1920	17,489	$2,264,387
1921	65,915	7,620,130
1922	168,077	8,720,775

Tons.

Baking powder, *see* Vol. II, Appendix XXXI

Bauxite & other aluminum ores & concentrates

1915	11,949	$ 531,404
1916	19,317	929,309
1917	18,495	1,118,777
1918	21,313	1,463,842
1919	18,187	1,397,200
1920	20,890	1,709,390
1921	13,081	1,066,732
1922	19,617	961,208

Tons.

Benzene

1918	25,400,852	$2,152,315
1919	24,402,278	1,236,282
1920	17,253,314	732,836
1921	66,622,862	3,182,721
1922	55,179,363	1,978,776

Bleaching powder, *see* Lime, chlorinated

Borax, refined

1920	10,943,110	$905,617
1921	4,368,880	385,650
1922	10,094,724	545,601

Calcium acetate, *see* Vol. III, Appendix XXXIII

Calcium carbide

1913	33,419,375	$ 990,027
1914	32,845,649	962,040
1915	35,772,867	1,097,952
1916	37,873,692	1,211,267
1917	31,278,971	1,001,861
1918	28,814,176	1,327,864
1919	21,278,167	1,537,984
1920	21,164,404	1,040,754
1921	20,147,753	967,024
1922	12,477,237	629,164

Coal tar & pitch

1913	121,168	$152,273
1914	22,150	43,145
1915	21,317	39,647
1916	74,809	129,220
1917	62,674	145,574
1918	53,955	147,765
1919	60,672	201,653
1920	81,640	192,294
1921	128,103	287,300
1922	76,653	159,078

Barrels, 280 lb.

Coal-tar distillates, crude, n.e.s.

1918	—	$5,620,851
1919	—	3,748,370
1920	—	3,618,424
1921	—	4,101,129
1922	—	154,983

Coal-tar medicinals

1913	—	$ 7,110,493
1914	—	6,721,978
1915	—	7,130,379
1916	—	8,397,971
1917	—	8,613,202
1918	—	10,190,188
1919	—	15,277,037
1920	—	20,124,561
1921	—	18,038,328
1922	—	224,546

Copper sulfate (blue vitriol), *see* Vol. III, Appendix XVIII

Dye extracts, n.e.s.

1918	—	$7,284,110
1919	—	6,125,394
1920	—	6,829,937
1921	—	3,571,309
1922	2,614,110	459,861

Dyes & dyestuffs

1913	—	$ 347,656
1914	—	356,919
1915	—	1,775,925
1916	—	5,102,002
1917	—	11,710,887

Stated separately after 1917.

Ferroalloys, tungsten, manganese, etc., n.e.s.

1917	1,784,306	$3,597,426
1918	2,184,769	4,056,437
1919	177,123	408,148
1920	17,494	57,820
1921	1,600	1,625
1922	303	13,189

In tons after 1921.

U. S. EXPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Ferrovanadium

1915	755,905	$ 641,792
1916	1,113,076	1,018,121
1917	2,613,387	2,831,669
1918	2,089,347	2,582,670
1919	637,604	770,862
1920	184,250	253,579
1921	450,070	916,147
1922	69,952	84,827

Fertilizers, n.e.s.

1913	74,834	$ 1,875,999
1914	61,601	1,360,903
1915	89,224	2,128,190
1916	124,979	3,580,543
1917	216,222	6,056,887
1918	89,190	4,808,337
1919	106,656	6,384,432
1920	241,215	20,583,984
1921	108,431	5,988,308
1922	41,529	1,539,512

Tons.

Flavoring extracts & fruit juices

1913	—	$ 133,990
1914	—	106,892
1915	—	136,742
1916	—	466,914
1917	—	581,550
1918	—	1,018,102
1919	—	949,726
1920	—	1,425,380
1921	—	1,236,135
1922	2,319,469	761,284

Formaldehyde solution

1918	—	$ 866,038
1919	—	797,671
1920	—	2,289,217
1921	—	1,376,281
1922	1,940,576	209,386

Gasoline, *see* Oil, mineral

Glycerin, *see* Vol. III, Appendix XLV

Kerosene, *see* Oil, mineral

Lampblack

1913	—	$ 505,748
1914	—	421,548
1915	—	368,825
1916	—	521,463
1917	—	917,303
1918	—	1,111,265
1919	—	1,102,767
1920	—	1,959,208
1921	—	1,829,987
1922	17,062,311	2,028,105

Lead carbonate, basic, *see* White lead

Lime

1913	284,685	$214,543
1914	285,749	200,437
1915	169,078	117,644
1916	258,538	143,182
1917	168,521	126,266
1918	142,525	150,197
1919	68,015	108,647
1920	54,424	111,162
1921	64,568	143,068
1922	54,179	87,386

Barrels, 200 lb.

Lime, chlorinated (bleaching powder)

1918	13,060,401	$ 558,066
1919	15,639,918	450,145
1920	31,232,379	840,092
1921	37,425,093	1,146,378
1922	26,439,251	502,870

Logwood extract & hematin crystals

1918	—	$2,339,480
1919	—	1,556,023
1920	—	1,832,231
1921	—	1,471,040
1922	2,626,103	448,713

Mercury, *see* Vol. III, Appendix LVII

Methanol, *see* Vol. III, Appendix XXXIII

Naphtha, *see* Oil, mineral

Naval stores, *see* Rosin; Turpentine

Nickel, oxide, matte, *see* Vol. III, Appendix XXII

Oil, mineral, crude (petroleum)

1913	195,642,935	$ 7,750,767
1914	146,477,342	6,812,672
1915	152,514,129	4,911,634
1916	163,734,200	5,754,279
1917	176,368,675	7,162,550
1918	185,069,674	9,288,979
1919	163,782,498	9,905,490
1920	356,542,830	24,263,884
1921	355,200,756	29,137,765
1922	378,975,150	16,366,428

Gallons.

Oil, mineral, illuminating (kerosene)

1913	1,048,894,297	$66,189,265
1914	1,157,283,310	74,500,162
1915	886,316,740	53,607,082
1916	823,164,882	54,288,788
1917	833,969,012	642,377

1918	528,217,669	$ 47,261,782
1919	725,686,746	81,495,706
1920	915,138,071	126,392,949
1921	833,194,727	128,089,900
1922	807,701,055	76,389,046

Gallons.

Oil, mineral, lubricating, n.e.s.

1918	259,385,874	$ 64,030,825
1919	265,552,016	84,982,874
1920	329,288,894	110,539,083
1921	332,274,197	136,495,631
1922	307,794,350	75,113,214

Gallons.

Oil, mineral, lubricating (including heavy paraffin)

1913	213,671,499	$29,574,410
1914	196,884,696	27,852,959
1915	214,429,099	28,499,786
1916	250,392,768	37,451,607
1917	271,028,546	48,649,557

Gallons; stated separately after 1917.

Oil, mineral, lubricating (paraffin)

1918	10,287,896	$2,131,292
1919	7,596,525	1,173,821
1920	6,823,644	1,527,773
1921	1,183,675	573,450
1922	15,077,854	2,996,612

Gallons.

Oil, mineral, refined (gasoline, naphtha, & other light products)

1913	101,821,572	$ 14,269,878
1914	40,840,730	5,653,210
1915	94,335,128	10,296,928
1916	194,644,803	29,472,233
1917	199,563,352	41,057,840
1918	209,029,477	52,739,227
1919	146,301,861	38,654,419
1920	184,761,512	50,537,352
1921	259,603,571	77,415,408
1922	550,478,181	117,630,281

Gallons.

Oil, mineral, residuum (including road oil)

1913	27,513,568	$ 496,237
1914	113,370,245	1,907,715
1915	9,952,970	230,552
1916	13,538,335	388,175
1917	551,967	33,813
1918	881,875	96,480
1919	181,121	14,557
1920	50,272,602	2,732,783
1921	9,825,633	609,302
1922	10,091,192	800,044

Gallons.

Oleostearin, *see* Stearin, animal

Paints, dry colors, n.e.s.

1914	—	$ 690,836
1915	—	1,072,736
1916	—	1,591,913
1917	—	1,810,393
1918	—	1,907,667
1919	—	2,808,980
1920	—	2,991,618
1921	—	2,170,237
1922	31,992,345	1,350,448

Paraffin

1913	290,678,861	$ 9,679,273
1914	186,357,728	6,516,338
1915	330,374,056	10,589,843
1916	360,650,114	12,873,250
1917	348,743,903	16,038,811

After 1917, see below.

Paraffin, refined

1918	164,159,159	$13,866,810
1919	185,078,571	19,642,149
1920	282,384,250	26,088,672
1921	203,289,734	17,524,258
1922	189,864,980	6,965,791

Paraffin, unrefined

1918	82,534,361	$4,677,280
1919	53,729,436	4,915,237
1920	79,023,341	5,377,069
1921	50,121,130	2,994,654
1922	69,651,581	2,039,943

Paraffin, *see also* Oil, mineral

Perfumery & toilet waters

1913	—	$1,441,982
1914	—	1,620,872
1915	—	1,715,059
1916	—	2,903,063
1917	—	3,618,620
1918	—	3,965,465
1919	—	6,077,854
1920	—	7,979,237
1921	—	6,236,766
1922	—	504,167

Petroleum, *see* Oil, mineral

Phenol, *see* Vol. II, Appendix XXIII

Phosphate rock, *see* Vol. II, Appendix XXIX

U. S. EXPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1913-22 (*Cont.*)

Plumbago or graphite, & manufactures (except crucibles)

1913	—	$ 175,583
1914	—	269,499
1915	—	368,333
1916	—	845,729
1917	—	1,296,305
1918	—	716,538
1919	—	862,544
1920	—	517,188
1922	2,028,463	255,019

Plumbago or graphite, unmanufactured

1913	4,503,569	$321,679
1914	5,376,880	387,075
1915	2,324,081	152,446
1916	936,869	46,907
1917	2,500,057	163,333
1918	4,912,730	331,369
1919	1,392,043	102,162
1920	1,306,859	107,552
1921	1,195,228	84,908
1922	1,893,881	90,183

Polishes, metal & stove

1913	—	$127,898
1914	—	162,504
1915	—	167,277
1916	—	225,783
1917	—	214,800
1918	—	192,691
1919	—	262,043
1920	—	451,934
1921	—	346,104
1922	3,602,952	400,186

Polishes, n.e.s.

1915	—	$ 503,629
1916	—	784,552
1917	—	1,036,234
1918	—	1,009,100
1919	—	2,077,319
1920	—	2,845,110
1921	—	2,072,963
1922	3,913,206	567,932

Potassium chlorate

1918	1,564,662	$681,128
1919	1,903,133	678,276
1920	2,845,858	475,034
1921	1,130,771	179,300
1922	447,730	46,252

Potassium compounds, n.e.s.

1918	—	$ 961,989
1919	—	1,318,188
1920	—	3,362,827
1921	—	1,309,852
1922	7,483,175	296,378

Quicksilver, *see* Vol. III, Appendix LVII

Red lead

1918	4,792,330	$567,854
1919	7,952,730	946,114
1920	3,072,731	348,907
1921	2,046,339	244,151
1922	2,015,696	168,724

Rosin, gum, *see* Vol. II, Appendix XLV

Sal soda, *see* Soda, hydrated

Soda, caustic, *see* Sodium hydroxide

Soda, hydrated (sal soda)

1918	14,076,264	$205,489
1919	10,675,870	186,382
1920	12,763,399	202,039
1921	10,376,424	207,539
1922	11,061,664	200,903

Soda ash

1918	198,752,457	$6,074,879
1919	191,864,329	6,261,518
1920	116,555,500	2,804,130
1921	113,481,062	3,308,783
1922	33,090,180	757,648

Sodium bicarbonate

1920	11,998,510	$360,601
1921	13,353,769	389,337
1922	14,803,631	347,233

Sodium borate, *see* Borax, refined

Sodium hydroxide (caustic)

1918	134,729,691	$8,629,086
1919	127,192,309	6,382,511
1920	229,146,363	9,321,902
1921	101,021,827	5,478,055
1922	123,126,777	4,660,815

Sodium salts & preparations

1915	—	$ 3,141,022
1916	—	12,649,854
1917	—	18,381,450

Not stated prior to 1915 & subdivided after 1917.

Sodium salts, n.e.s.

1918.........	—	$7,421,521
1919.........	—	6,475,158
1920.........	—	7,485,008
1921.........	—	5,378,899
1922.........	97,518,434	2,439,113

Sodium silicate (water glass)

1918.........	26,125,740	$373,822
1919.........	26,009,043	400,508
1920.........	33,692,535	420,124
1921.........	23,099,660	321,972
1922.........	26,024,366	279,041

Stearin, animal

1915.........	11,457,907	$1,083,665
1916.........	13,062,247	1,461,661
1917.........	12,936,357	1,798,317
1918.........	10,360,030	2,181,317
1919.........	11,537,284	2,309,979
1920.........	22,505,608	4,717,748
1921.........	19,177,311	2,429,414
1922.........	33,017,879	3,183,684

Stearin, vegetable

1917.........	1,321,773	$179,092
1918.........	1,226,127	248,585
1919.........	782,467	166,423
1920	5,138,225	962,394
1921.........	1,848,313	224,576
1922.........	1,949,422	194,596

Sulfur, *see* Vol. II, Appendix XXXIII

Superphosphate (acid phosphates)

1917.........	6,508	$ 67,489
1918.........	6,155	202,268
1919.........	51,405	1,548,198
1920.........	93,432	3,099,855
1921.........	29,954	1,311,054
1922.........	14,806	267,739

Tons.

Tanning materials, *see* Dyeing

Tar, coal, *see* Coal tar

Tar, turpentine & pitch

1914.........	351,352	$568,891
1915.........	239,661	430,612
1916.........	67,963	291,731
1917.........	103,397	561,566
1918.	82,030	598,211
1919.........	48,030	384,263
1920.........	61,790	534,175
1921.........	41,748	377,649
1922 (July 1-Dec. 1)	9,817	63,158

Barrels.

Trinitrophenol, *see* Acid, picric

Turpentine, *see* Vol. II, Appendix XLV

Washing powders & fluids

1913.........	9,923,700	$756,762
1914.........	12,761,958	535,635
1915.........	14,695,317	635,476
1916.........	7,875,317	355,926
1917.........	3,517,441	197,614
1918.........	4,754,804	243,184
1919	3,984,745	231,786
1920.........	6,114,816	357,074
1921.........	4,021,497	267,597
1922.........	3,346,375	201,609

White lead

1914.........	16,845,154	$1,013,506
1915.........	19,700,810	1,070,646
1916.........	29,107,449	1,861,730
1917.........	21,388,938	1,944,145
1918.........	18,235,783	2,072,352
1919.........	20,462,348	2,337,318
1920.........	34,441,918	3,598,913
1921.........	17,408,803	1,895,696
1922.........	8,945,730	672,211

Zinc oxide, *see* Vol. III, Appendix XXIV

Appendix V

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Abrasives, artif., crude	10%	Free	Free
ground	—	1¢ lb.	1¢ lb.
Acenaphthene	20%	5%	Free
Acetaldehyde & acetaldol	25%	15%	6¢ lb. & 30%
Acetanilide, med	25%	25%	7¢ lb. & 60%[a, c]
non-med	20% (n.e.)	25%	7¢ lb. & 55%[a, b]
Acetone & acetone oil	25%	1¢ lb.	25%
Acetphenetidine	25%	25%	7¢ lb. & 60%[a, c]
Acid, acetic, under 65%	¾¢ lb.	Free	¾¢ lb.
over 65%	2¢ lb.	Free	2¢ lb.
anhydride	2½¢ lb.	2½¢ lb.	5¢ lb.
acetylsalicylic	25%	25%	7¢ lb. & 60%[a, c]
aminobenzoic	20%	15%	7¢ lb. & 55%[a, b]
aminosalicylic	Free	10%	7¢ lb. & 55%[a, b]
arsanilic	20%	15%	7¢ lb. & 55%[a, b]
arsenic	Free	Free	3¢ lb.
arsenious	Free	Free	Free
benzoic, med	Free	15%	7¢ lb. & 60%[a, c]
non-med	Free	15%	7¢ lb. & 55%[a, b]
boric	3¢ lb.	¾¢ lb.	1½¢ lb.
chloroacetic	25%	15%	5¢ lb.
chlorophthalic	20%	15%	7¢ lb. & 55%[a, b]
chromic	2¢ lb.	Free	Free
cinnamic	20%	15%	7¢ lb. & 55%[a, b]
citric	7¢ lb.	5¢ lb.	17¢ lb.
dichlorophthalic	20%	15%	7¢ lb. & 55%[a, b]
fluoric	Free	Free	Free
formic	25%	1½¢ lb.	25%
gallic	8¢ lb.	6¢ lb.	8¢ lb.
glycerophosphoric, salts & comp	25%	25%	35%
hydrochloric & hydrofluoric	Free	Free	Free
hydroxyphenylarsinic	20%	15%	7¢ lb. & 55%[a, b]
lactic (not less than 25% ad valorem, anhydrides determined as acids)	2-3¢ lb.	1½¢ lb.	—
to 30%	2¢ lb.	1½¢ lb.	2¢ lb.
30-55%	2¢ lb.	1½¢ lb.	4¢ lb.
55% & over	3¢ lb.	1½¢ lb.	9¢ lb.
metanilic	Free	10%	7¢ lb. & 55%[a, b]
mixed (sulfuric-nitric)	25%	Free (n.e.)	Free
muriatic	Free	Free	Free
nitric	Free	Free	Free

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Acid, oleic (red oil)........	25%	15%	1½¢ lb.
oxalic.................	2¢ lb.	1½¢ lb.	4¢ lb.
phenylglycine-*o*-carboxylic	20%	15%	7¢ lb. & 55%[a, b]
phosphoric.............	Free	Free	2¢ lb.
phthalic...............	Free	Free	7¢ lb. & 55%[a, b]
anhydride............	20%	Free	7¢ lb. & 55%[a, b]
picric..................	Free	15%	7¢ lb. & 60%[a, c]
prussic................	Free	Free	25%
pyrogallic.............	25%	12¢ lb.	12¢ lb.
ricinoleic..............	15-30¢ gal.	25%	35%
salicylic, med...........	5¢ lb.	2½¢ lb.	7¢ lb. & 60%[a, c]
salts..............	25%	15%	7¢ lb. & 60%[a, c]
non-med.............	5¢ lb.	2½¢ lb.	7¢ lb. & 55%[a, b]
salts..............	20%	15%	7¢ lb. & 55%[a, b]
silicic..................	Free	Free	25%
stearic................	25%	15%	1½¢ lb.
sulfanilic..............	20%	15%	7¢ lb. & 55%[a, b]
sulforicinoleic..........	15-30¢ gal.	25%	35%
sulfuric...............	¼¢ lb.	Free	Free
tannic.................	35¢ lb. (tannin & tannic acid)		
to 50%.............		5¢ lb. (tannin & tannic acid)	4¢ lb.
50% & over, med.....	¼¢ lb. & 10% (aq. ext. nutgalls, non-med.)	⅜¢ lb. (nutgalls ext. & decoc.)	20¢ lb.
non-med...........		5¢ lb.	10¢ lb.
tartaric...............	5¢ lb.	3½¢ lb.	6¢ lb.
tetrachlorophthalic......	20%	15%	7¢ lb. & 55%[a, b]
thiosalicylic............	20%	15%	7¢ lb. & 55%[a, b]
tungstic..............	25%	15%	60¢ lb. & 25%
valeric...............	Free	Free	Free
n.s.p.f., incl. anhydrides.	25%	15%	25%
Adonite................	25%	15%	50%
Alcohol, amyl...........	¼¢ lb.	¼¢ lb.	6¢ lb.
butyl................	¼¢ lb.	¼¢ lb.	6¢ lb.
ethyl, mixt. & comp.			
up to 20%..........	60¢ lb. & 25%	10¢ lb. & 20%	20¢ lb. & 25%
20-50%.............	60¢ lb. & 25%	20¢ lb. & 20%	40¢ lb. & 25%
over 50%	60¢ lb. & 25%	40¢ lb. & 20%	80¢ lb. & 25%
non-beverage.........	$2.60 proof gal.	$2.60 proof gal.	15¢ gal.
methyl (wood alc.)......	20% (n.e.)	Free	12¢ gal.
phenylethyl...........	20%	20%	7¢ lb. & 60%[a, c]
propyl................	25%	¼¢ lb.	6¢ lb.
Aldehyde ammonia & aldol.	25%	15%	6¢ lb. & 30%
Alizarin, natural & deriv...	Free	Free	7¢ lb. & 60%[a, c]
Alkalies & alkaloids, n.s.p.f.	25%	15%	25%
Alloys, for steel, n.s.p.f.....	20%	15%	25%
Alum..................	¼-⅜¢ lb.	15%	3/10-⅛¢ lb.
Aluminum, & alloys, crude.	7¢ lb.	2¢ lb.	5¢ lb.
foil, less .006 in.........	45%	20%	35%

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS (*Continued*)

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Aluminum, powder	12¢ lb.	25%	12¢ lb.
salts & comp., n.s.p.f.	25%	15%	25%
Aluminum hydroxide	4/10-6/10¢ lb.	15%	½¢ lb.
-silicon	—	—	25%
sulfate (alum cake), to 15% Al & Fe over .1% Fe_2O_3 equiv.	¼-⅜¢ lb.	15%	8/10¢ lb.
over 15% Al & Fe to .1% Fe_2O_3 equiv.	¼-⅜¢ lb.	15%	⅜¢ lb.
Aminoanthraquinone, aminonaphthol, aminophenetole, aminophenol	20%	15%	7¢ lb. & 55%[a, b]
Ammonia, anhyd., liq.	5¢ lb.	2½¢ lb.	2½¢ lb.
Ammonia alum (ammonium aluminum sulfate)	¼-⅜¢ lb.	15%	¾¢ lb.
Ammonium bicarbonate	25%	15%	1½¢ lb.
carbonate	1½¢ lb.	¾¢ lb.	1½¢ lb.
chloride (sal ammoniac)	¾¢ lb.	¾¢ lb.	1¼¢ lb.
nitrate	25%	Free	1¢ lb.
perchlorate	25%	Free	1½¢ lb.
phosphate	25% (n.e.)	1¢ lb.	1½¢ lb.
sulfate	Free	Free	¼¢ lb.
Amyl acetate	50¢ lb. or 25% min.	5¢ lb.	25%
nitrate	50¢ lb. or 25% min.	20%	25%
Anethole	25%	20%	45%
Anhydrides, n.s.p.f.	25%	15%	25%
Aniline oil, & salt	Free	10%	7¢ lb. & 55%[a, b]
Anthracene, to 30%	20%	Free	Free
30% & over	20%	Free	7¢ lb. & 55%[a, b]
Anthracene oil	20%	Free	Free
Anthraquinone	20%	15%	7¢ lb. & 55%[a, b]
Antimony	1½¢ lb.	10%	2¢ lb.
liquated	1¢ lb.	10%	¼¢ lb.
salts & comp., n.s.p.f.	25%	15% (n.e.)	1¢ lb. & 25%
Antimony oxide	1½¢ lb. & 25%	25%	2¢ lb.
-potassium tartrate	25%	25%	6¢ lb.
sulfide	25%	15% (n.e.)	1¢ lb. & 25%
Antipyrine	25%	25%	7¢ lb. & 60%[a, c]
Arabinose	25%	15%	50%
Argols, tartar, & wine lees, crude or partly ref., to 90% K bitartrate	3¢ lb. (partly ref.) 5% (crude)	5%	5%
over 90%	4¢ lb. (partly ref.) 5% (crude)	2½¢ lb.	5¢ lb.
Arsenic	Free	Free	6¢ lb.
sulfide, other salts & comp., n.s.p.f., 10% & over arsenious acid	Free	Free	Free

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Aspirin	25%	25%	7¢ lb. & 60% [a, c]
Azides	30%	Free	12½¢ lb.
Barium carbonate, precip.	25% (n.e.)	15%	1¢ lb.
chloride	25% (n.e.)	¼¢ lb.	1¼¢ lb.
dioxide	25% (n.e.)	1½¢ lb.	4¢ lb.
hydroxide	25%	15%	1¼¢ lb.
nitrate	25%	15%	2¢ lb.
sulfate, precip.	½¢ lb.	20%	1¢ lb.
Barytes, crude	$1.50 ton	15%	$4 ton
ground	$5.25 ton	20%	$7.50 ton
Bauxite, crude	$1 ton	Free	$1 ton
ref.	4/10-6/10¢ lb.	15%	½¢ lb.
Benzalchloride	20%	15%	7¢ lb. & 55% [a, b]
Benzaldehyde, med.	Free	15%	7¢ lb. & 60% [a, c]
non-med.	Free	10%	7¢ lb. & 55% [a, b]
Benzanthrone	20%	15%	7¢ lb. & 55% [a, b]
Benzene	Free	5%	Free
Benzidine, & sulfate	Free	10%	7¢ lb. & 55% [a, b]
Benzoquinone	20%	15%	7¢ lb. & 55% [a, b]
Benzoyl chloride	20%	15%	7¢ lb. & 55% [a, b]
Benzyl acetate, & benzoate	20%	20%	7¢ lb. & 60% [a, c]
chloride	Free	10%	7¢ lb. & 55% [a, b]
Benzylethylaniline	20%	15%	7¢ lb. & 55% [a, b]
Bismuth	Free	Free	7½%
comp., salts, mixt.	25% (n.e.)	10%	35%
Black pigments (carbon, gas, lampblack), n.s.p.f.	25%	15%	20%
Blanc fixe	½¢ lb.	20%	1¢ lb.
Bleaching powder	1/5¢ lb.	1/10¢ lb.	8/10¢ lb.
Blue pigments, & all with iron ferri- or ferrocyanide	8¢ lb.	20%	8¢ lb.
Bone black, chars & carbon	20-25%	Free (non-pigment) 15% (pigment)	20%
Borax & borates, crude, n.s.p.f.	2¢ lb.	Free	Free
Bromine	25%	Free	10¢ lb.
comp., n.s.p.f.	25%	15%	10¢ lb.
Bromobenzene	20%	15%	7¢ lb. & 55% [a, b]
Butyraldehyde	25%	15%	6¢ lb. & 30%
Cadmium	Free	Free	15¢ lb.
Caffeine	25% (n.e.)	$1 lb.	$1.50 lb.
comp.	25% (n.e.)	25%	25%
Calcium acetate, crude	25%	Free	Free
borate	2¢ lb.	Free	Free
carbide	25% (n.e.)	Free	1¢ lb.
chloride, crude	25%	Free	Free
cyanamide	Free	Free	Free
molybdate	25%	15%	50¢ lb. & 15%
nitrate	25%	Free	Free

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS (*Continued*)

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Calcium silicide	20%	15%	25%
sulfate, precip.	½¢ lb. or 20%	10-20%	½¢ lb.
tartrate, crude	25% (n.e.)	5%	5%
Calomel, & Hg prep.	35%	15%	45%
Camphor, crude, natural	Free	1¢ lb.	1¢ lb.
ref., synth.	6¢ lb.	5¢ lb.	6¢ lb.
Carbazole, to 65%	20%	5%	Free
65% & over	20%	15%	7¢ lb. & 55%[a, b]
Carbon tetrachloride	25%	1¢ lb.	2½¢ lb.
Carbons (*see* Black, Bone black)			
Cellulose esters & ethers			
comp., unfinished	45¢ lb.	25%	40¢ lb.
finished, partly finished	65¢ lb. & 30%	40%	60%
vulcanized	35%	25%	35%
sol	25%	20%	35¢ lb.
Cerium	Free	Free	$2 ton
alloys	20%	10%	$2 lb. & 25%
Cerium fluoride, nitrate, salts, n.s.p.f.	25%	15%	35%
Chalk (whiting, Paris white), dry	¼¢ lb. (dry) 1¢ lb. (ground)	1/10¢ lb.	25%
ground in oil	½¢ lb.	15%	¾¢ lb.
precipitated	1¢ lb.	25%	25%
(*see also* French chalk)			
Charcoal, non-pigment	20%	Free	Free
Chemical elements, mixt.			
to 20% alc.	55¢ lb. or 25% min.	10¢ lb. & 20%	20¢ lb. & 25%
20-50%	55¢ lb. or 25% min.	20¢ lb. & 20%	40¢ lb. & 25%
over 50%	55¢ lb. or 25% min.	40¢ lb. & 20%	80¢ lb. & 25%
n.s.p.f.	25%	15%	25%
Chemicals, drugs, etc., capsules, pills, tablets, etc. (med. doses)	25%	25%	25% min.
Chemicals, photographic	20%	15%	7¢ lb. & 60%[a, c]
synth. odoriferous or aromatic, mixed, n.s.p.f.	25%	20%	40¢ lb. & 50%
unmixed, n.s.p.f.	20%	20%	7¢ lb. & 60%[a, c]
synth. org. (non-coal tar)	—	15%	25%
Chestnut ext.	15%	Free	15%
Chloral hydrate	55¢ lb. (n.e.); 25% min.	25%	35%
Chlorinated lime	⅕¢ lb.	1/10¢ lb.	3/10¢ lb.
Chlorobenzene	20%	15%	7¢ lb. & 55%[a, b]
Chloroform	10¢ lb.	2¢ lb.	6¢ lb.
Chrome, chromium	20-25%	15%	30%
Chrome yellow, green, etc.	4⅜¢ lb.	20%	25%
Citral	25%	20%	45%
Clays or earths, China or kaolin	$2.50 ton	$1.25 ton	$2.50 ton

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Clays or earths, crude, n.s.p.f.	$1 ton	50¢ ton	$1 ton
mfd., n.s.p.f.	$2 ton	$1 ton	$2 ton
Cleaning & polishing prep., n.s.p.f. (non-alc.)	25%	15%	25%
Coal tar, crude	Free	Free	Free
distillates, to 5% tar acids below 190° C., non-med. colors, dyes	Free	Free	Free
5% & over tar acids	20%	5%	7¢ lb. & 55%[a, b]
intermediates, n.s.p.f.	20%	15%	7¢ lb. & 55%[a, b]
Coal-tar chemicals: colors, dyes, stains	30%	30%	7¢ lb. & 60%[a, c]
color acids, bases, lakes; leuco comp., indoxyl comp.	20%	15%	7¢ lb. & 55%[a, b]
Cobalt	Free	Free	Free
salts & comp., n.s.p.f.	25%	15%	30%
Cobalt linoleate	25%	15%	10¢ lb.
oxide	25¢ lb.	10¢ lb.	20¢ lb.
sulfate	25%	15%	10¢ lb.
Cocaine, salts, esters, deriv.	$1.50 oz.	$2 oz.	$2.60 oz.
Collodion, & other pyroxylin sol.	40¢ lb.	15%	35¢ lb.
finished, partly finished articles	65¢ lb. & 30%	40%	60%
unfinished articles	35%	25%	40¢ lb.
Coloring for liquors	50%	40%	15%
Copper acetate, & subacetate	Free	Free	Free
sulfate (blue vitriol)	¼¢ lb.	Free	Free
Copperas (ferrous sulfate)	15/100¢ lb.	Free	Free
Corrosive sublimate	35%	15%	45%
Corundum	Free	Free	1¢ lb.
Coumarin, natural	25%	15%	7¢ lb. & 60%[a, c]
synth.	20%	20%	7¢ lb. & 60%[a, c]
Cream of tartar	5¢ lb.	2½¢ lb.	5¢ lb.
Creosote oil, & dead	Free	Free	Free
Cresol (*o*-,*m*-,*p*-), 90% or over	Free	Free	7¢ lb. & 55%[a, b]
Crotonaldehyde	25%	15%	6¢ lb. & 30%
Cryolite	Free	Free	Free
Cumene	20%	5%	Free
Cumidine	Free	10%	7¢ lb. & 55%[a, b]
Cyanides, & mixt., comp. n.s.p.f.	25%	15%	Free
Cymene	20%	5%	Free
Dehydrothiotoluidine	20%	15%	7¢ lb. & 55%[a, b]
Dextrin (potato, flour)	1½¢ lb.	1¼¢ lb.	2¼¢ lb.
n.s.p.f.	1½¢ lb.	¾¢ lb.	1¼¢ lb.

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS (*Continued*)

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Dextrose, to 99.7%	1½¢ lb.	1⅛¢ lb.	1½¢ lb.
over 99.7%	25%	15%	50%
Diaminostilbene	20%	15%	7¢ lb. & 55%[a, b]
Dianisidine	Free	10%	7¢ lb. & 55%[a, b]
Diethyl sulfate	50¢ lb. or 25% min.	20%	25%
Dihydroxynaphthalene	20%	15%	7¢ lb. & 55%[a, b]
Dimethylaminophenol	20%	15%	7¢ lb. & 55%[a, b]
Dimethylaniline	Free	10%	7¢ lb. & 55%[a, b]
Dimethylphenylbenzylammonium hydroxide	20%	15%	7¢ lb. & 55%[a, b]
Dimethylphenylenediamine	20%	15%	7¢ lb. & 55%[a, b]
Dimethyl sulfate	50¢ lb. or 25% min.	20%	25%
Dinitrobenzene, dinitrochlorobenzene	Free	10%	7¢ lb. & 55%[a, b]
Dinitronaphthalene, dinitrophenol	20%	15%	7¢ lb. & 55%[a, b]
Dinitrotoluene	Free	10%	7¢ lb. & 55%[a, b]
Diphenylamine	Free	10%	7¢ lb. & 55%[a, b]
Diphenyloxide	20%	20%	7¢ lb. & 60%[a, c]
Dulcite	25%	15%	50%
Dyeing & tanning ext., non-alc., n.s.p.f.	15%	⅜¢ lb.	15%
Dyeing & tanning materials, non-alc., vegetable, n.s.p.f.	Free	Free	Free
Dynamite	2-4¢ lb.	Free	1¼¢ lb.
Earths (ochers, siennas, umbers), crude	⅛¢ lb.	5%	⅛¢ lb.
ground	⅛-1¢ lb.	5%	⅜¢ lb.
Ecgonine, salts, esters, deriv.	$1.50 oz.	$2 oz.	$2.60 oz.
Emery, ground	—	1¢ lb.	1¢ lb.
Epsom salt (magnesium sulfate	⅕¢ lb.	⅒¢ lb.	½¢ lb.
Esters & ethers, n.s.p.f., to 10% alc.	50¢ lb. or 25% min.	20%	25%
Ethyl acetate	50¢ lb. or 25% min.	5¢ lb.	3¢ lb.
chloride	30%	20%	15¢ lb.
ether (sulfuric ether)	8¢ lb. or 25% min.	4¢ lb.	4¢ lb.
methyl ketone	25%	15%	25%
nitrite (spirits nitrous ether)	20¢ lb.	20%	25%
Ethylene chlorohydrin, dichloride, glycol, oxide	25%	15%	6¢ lb. & 30%
Explosives (coal-tar, excl. smokeless)	2-4¢ lb.	Free	7¢ lb. & 60%[a, c]
Extracts, flavoring, non-alc., n.s.p.f.	25%	20%	25%
tanning & dyeing, non-alc., n.s.p.f.	15%	⅜¢ lb.	15%

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Ferroalloys (B, P, Si, Ti, U, V, Zr)	20-25%	15%	25%
Ferrocerium	20%	10%	$2 lb. & 25%
Ferrochrome, ferrochromium, to 3% C	20-25%	15%	30%
over 3% C	20-25%	15%	3½¢ lb.
Ferromanganese, over 1% C	$2.50 ton	Free	1⅞¢ lb.
Ferromolybdenum	20-25%	15%	50¢ lb. & 15%
Ferrosilicon, 8-60% Si	$5 ton or 20%	15%	2¢ lb.
60-80%	20%	15%	3¢ lb.
80-90%	20%	15%	4¢ lb.
over 90%	20%	15%	8¢ lb.
Ferrosilicon-aluminum	20-25%	15%	25%
Ferrotungsten	20-25%	15%	60¢ lb. & 25%
Ferrous sulfate (copperas)	15/100¢ lb.	Free	Free
Flavoring ext., alc. (*see* Alcohol, ethyl)			
non-alc.	25%	20%	25%
Fluorene	20%	5%	Free
Fluospar, over 93% CaF_2	$3 ton	$1.50 ton	$5.60 ton
Formaldehyde (formalin)	25%	1¢ lb.	2¢ lb.
solid (paraformaldehyde)	25%	15%	8¢ lb.
French chalk, crude	Free	Free	¼¢ lb.
ground	1¢ lb. or 20%	15%	25%
Fuller's earth, crude	$1.50 ton	75¢ ton	$1.50 ton
mfd.	$3 ton	$1.50 ton	$3.25 ton
Fulminates	20%	Free	12½¢ lb.
Fusel oil & mixt.	¼¢ lb.	¼¢ lb.	6¢ lb.
Galactose	25%	15%	50%
Geraniol	25%	20%	45%
Glycerin, crude	1¢ lb.	1¢ lb.	1¢ lb.
ref.	3¢ lb.	2¢ lb.	2¢ lb.
Glycol monoacetate	25%	15%	6¢ lb. & 30%
Gold, chem. comp.	25% (n.e.)	10%	25%
Graphite, amorphous	Free	Free	10%
cryst., flake	Free	Free	1½¢ lb.
lump	Free	Free	20%
Guaiacol, natural & deriv.	25% (n.e.)	15-25%	7¢ lb. & 60% [a, c]
synth. & deriv.	25%	15%	7¢ lb. & 60% [a, c]
Guaiacol carbonate	25%	25%	7¢ lb. & 60% [a, c]
Gums & resins, synth.	20%	15%	7¢ lb. & 60% [a, c]
Gunpowder & explosives, n.s.p.f.	—	Free	Free
Gypsum, crude	30¢ ton	10%	Free
ground, calc.	$1.75 ton or 20%	10%	$1.40 ton
Heliotropin	25%	20%	45%
Hexamethylenetetramine	25%	15%	25%
Indigo, natural, synth.	Free (natural) ¾-10¢ lb. (ext.)	Free	7¢ lb. & 60% [a, c]
Ink powders, coal-tar	25%	15%	7¢ lb. & 60% [a, c]
n.s.p.f.	25%	15%	20%

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS (*Continued*)

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Inosite & inulin	25%	15%	50%
Iodine, crude	Free	Free	Free
resublimed	20¢ lb.	Free	20¢ lb.
Iodoform	75¢ lb.	15¢ lb.	25%
Ionone	25%	20%	45%
Iridium, & comb.	Free	Free	Free
Iron oxide & hydroxide pigments, n.s.p.f.	30%	10%	20%
(*see also* Ferro, Ferrous)			
Kaolin	$2.50 ton	$1.25 ton	$2.50 ton
Laudanum	40%	60%	60%
Lead, alloys, n.s.p.f.	2⅛¢ lb.	25%	2⅛¢ lb.
comp. & pigments, n.s.p.f.	25%	20%	30%
Lead acetate, brown, gray, yellow	2¢ lb.	1¢ lb.	2¢ lb.
white	3¢ lb.	1¼¢ lb.	2½¢ lb.
(*see also* Pigments)			
arsenate	25%	20%	3¢ lb.
nitrate	2¼¢ lb.	1¼¢ lb.	3¢ lb.
resinate	25%	20%	3¢ lb.
Levulose	25%	15%	50%
Lime, chlorinated (bleach)	⅕¢ lb.	1/10¢ lb.	3/10¢ lb.
hydrated, gross wt.	5¢ cwt.	5%	12¢ cwt.
n.s.p.f., gross wt.	5¢ cwt.	5%	10¢ cwt.
Lime citrate	Free	1¢ lb.	7¢ lb.
nitrogen (calcium cyanamide)	Free	Free	Free
Litharge	2½¢ lb.	25%	2½¢ lb.
Lithopone, & other ZnS-Ba_2SO_4 comb.	1¼¢ lb. (n.e.)	15%	1¾¢ lb.
Logwood	⅞¢ lb.	Free	15%
London purple	15%	Free	15%
Lupulin	50%	50%	75¢ lb.
Magnesite, caustic, calc.	Free	Free	⅝¢ lb.
crude	Free	Free	5/16¢ lb.
dead burned, grained	Free	Free	23/40¢ lb.
Magnesium, & alloys, mfd. n.s.p.f.	3¢ lb. & 25%	25%	40¢ lb. & 20%
Magnesium carbonate, precip.	3¢ lb.	1½¢ lb.	1½¢ lb.
chloride, anhyd.	25%	15%	1¢ lb.
n.s.p.f.	25%	15%	⅝¢ lb.
oxide (calc. magnesia), med.	7¢ lb.	3½¢ lb.	3½¢ lb.
non-med.	3¢ lb.	3½¢ lb.	3½¢ lb.
sulfate (Epsom salt)	⅕¢ lb.	1/10¢ lb.	½¢ lb.
Manganese, & alloys	20%	10%	1⅞¢ lb. & 15%
ore, over 30% Mn	Free	Free	1¢ lb.
salts & comp.	25%	15%	25%
Manganese oxide	Free	Free	—

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Mannite & mannose	25%	15%	50%
Melezitose & melibiose	25%	15%	50%
Menthol	25% (n.e.)	50¢ lb.	50¢ lb.
Mercury	7¢ lb.	10%	25¢ lb.
prep.	35%	15%	45%
Methylanthracene	20%	5%	Free
Methyl anthranilate	20%	20%	7¢ lb. & 60%[a, c]
Methylanthraquinone	20%	15%	7¢ lb. & 55%[a, b]
Methylnaphthalene	20%	5%	Free
Methyl salicylate, natural	25%	20%	7¢ lb. & 60%[a, c]
synth.	20%	20%	7¢ lb. & 60%[a, c]
Mineral salts (from mineral waters)	Free	Free	Free
Molybdenum, ore	Free	Free	35¢ lb.
powder (Fe, Ca, comp. & alloys)	20-25%	15%	50¢ lb. & 15%
Morphine, & sulfate	$1.50 oz.	$3 oz.	$3 oz.
Musk, natural	Free	20%	20%
synth.	20%	20%	7¢ lb. & 60%[a, c]
Naphthalene, solid. pt. to 79° C.	Free	Free	Free
solid. pt. 79° C. & over	Free	Free	7¢ lb. & 55%[a, b]
α-Naphthol	Free	5%	7¢ lb. & 55%[a, b]
β-Naphthol, med.	Free	15%	7¢ lb. & 60%[a, c]
non-med.	Free	5%	7¢ lb. & 55%[a, b]
Naphthylamine	Free	10%	7¢ lb. & 55%[a, b]
Naphthylenediamine	20%	15%	7¢ lb. & 55%[a, b]
Nickel oxide	6¢ lb.	10%	1¢ lb.
Niter cake	$1 ton	Free	Free
Nitroaniline	Free	10%	7¢ lb. & 55%[a, b]
Nitroanthraquinone & nitrobenzaldehyde	20%	15%	7¢ lb. & 55%[a, b]
Nitrobenzene	Free	10%	7¢ lb. & 55%[a, b]
Nitronaphthalene, nitrophenol, nitrophenylenediamine, nitrosodimethylaniline	20%	15%	7¢ lb. & 55%[a, b]
Nitrotoluene	Free	10%	7¢ lb. & 55%[a, b]
Nitrotoluylenediamine	20%	15%	7¢ lb. & 55%[a, b]
Nitrous ether, spirits	20¢ lb.	20%	25%
Ochers, crude	⅛¢ lb.	5%	⅛¢ lb.
ground	⅛-1¢ lb.	5%	⅜¢ lb.
Opium, alkaloids, salts, esters, deriv.	$1.50 oz.	$3 oz.	$3 oz.
crude, to 8.5% anhyd. morphine	$6 lb. (to 9%)	$6 lb.	$6 lb.
8.5% anhyd. morphine & over	$1.50 lb. (9% & over)	$3 lb.	$3 lb.
powd.	$2 lb.	$4 lb.	$4 lb.
tinct. & other liq. prep., n.s.p.f.	40%	60%	60%

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS (*Continued*)

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Orange mineral	3½¢ lb.	25%	3¢ lb.
Osmium, & comb.	Free	Free	Free
Palladium, & comb.	Free	Free	Free
Paracetaldehyde	25%	15%	6¢ lb. & 30%
Paraformaldehyde	25%	15%	8¢ lb.
Paris green	15%	Free	15%
Paris white (*see* Chalk)			
Phenol	Free	Free	7¢ lb. & 55%[a, b]
Phenolic resin	20%	15%	7¢ lb. & 60%[a, c]
Phenolphthalein	25%	25%	7¢ lb. & 60%[a, c]
Phenylacetaldehyde	20%	20%	7¢ lb. & 60%[a, c]
Phenylenediamine, phenylglycine, phenylhydrazine, phenylnaphthylamine	20%	15%	7¢ lb. & 55%[a, b]
Phosphates, crude, & apatite	Free	Free	Free
Phosphorus	18¢ lb.	Free	8¢ lb.
Photographic chemicals (coal-tar)	20%	15%	7¢ lb. & 60%[a, c]
Phthalimide	20%	15%	7¢ lb. & 55%[a, b]
Pigments, iron-oxide & iron-hydroxide	30%	10%	20%
lead, n.s.p.f.	2½-4⅞¢ lb.	25%	30%
n.s.p.f.	30-35%	15-20%	25%
(*see also* Lead; individual colors)			
Platinum, comp. & mixt.	25% (n.e.)	10%	25%
unmfd.	Free	Free	Free
Plumbago (*see* Graphite)			
Potassium-aluminum sulfate (potash alum)	¼-⅜¢ lb.	15%	¾¢ lb.
-antimony tartrate	25%	25%	6¢ lb.
bicarbonate	25%	½¢ lb.	1½¢ lb.
bichromate	2¼¢ lb.	1¢ lb.	2¼¢ lb.
bitartrate (*see* Argols)			
bromide	25%	15%	10¢ lb.
carbonate	Free	Free	¾¢ lb.
chlorate	2¢ lb.	½¢ lb.	1½¢ lb.
chloride	Free	Free	Free
chromate	2¼¢ lb.	1¢ lb.	2¼¢ lb.
cyanide	12½¢ lb.	Free	Free
ferricyanide (red prussiate)	8¢ lb.	2¢ lb.	7¢ lb.
ferrocyanide (yellow prussiate)	4¢ lb.	1¼¢ lb.	4¢ lb.
hydroxide (caustic potash)	Free	Free (crude) 2¢ lb. (ref.)	1¢ lb.
iodide	25¢ lb.	15¢ lb.	25¢ lb.

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Potassium nitrate (saltpeter), crude	Free	Free	Free
ref.	½¢ lb.	$7 ton	½¢ lb.
perchlorate	25%	15%	1½¢ lb.
permanganate	25%	1¢ lb.	4¢ lb.
-sodium tartrate (Rochelle salt)	3¢ lb.	2½¢ lb.	5¢ lb.
sulfate	Free	Free	Free
Potassium salts, crude, n.s.p.f.	Free	Free	Free
Propylene chlorohydrin, dichloride, glycol	25%	15%	6¢ lb. & 30%
Pyridine	20%	5%	Free
Pyrites	Free	Free	Free
Pyroxylin, comp., finished or partly finished	65¢ lb. & 30%	40%	60%
unfinished	35%	25%	40¢ lb.
liq. sol.	40¢ lb.	15%	35¢ lb.
Quicksilver	7¢ lb.	10%	25¢ lb.
Quinaldine	20%	15%	7¢ lb. & 55%[a, b]
Quinine sulfate, & cinchona alkaloids & salts	Free	Free	Free
Quinoline	20%	15%	7¢ lb. & 55%[a, b]
Radium, & salts, radioactive substances	Free	Free	Free
Raffinose	25%	15%	50%
Red lead	2⅝¢ lb.	25%	2¾¢ lb.
Resins: phenol, cresol, phthalic anhydride, coumarone, indene, etc.	20%	15%	7¢ lb. & 60%[a, c]
Resorcinol, med.	Free	5%	7¢ lb. & 60%[a, c]
non-med.	Free	5%	7¢ lb. & 55%[a, b]
Rhamnose	25%	15%	50%
Rhodinol	25%	20%	45%
Rhodium, comp. & mixt.	25% (n.e.)	10%	25%
natural	Free	Free	Free
Ribose	25%	15%	50%
Rochelle salt (potassium-sodium tartrate)	3¢ lb.	2½¢ lb.	5¢ lb.
Rosin, gum & spirits	Free	Free	Free
Ruthenium, & comb.	Free	Free	Free
Saccharides, n.s.p.f.	25%	15%	50%
Saccharin	65¢ lb.	65¢ lb.	7¢ lb. & 60%[a, c]
Safrole	25%	20%	45%
Sal ammoniac (ammonium chloride)	¾¢ lb.	¾¢ lb.	1¼¢ lb.
Salicin	Free	Free	50%
Salol	25%	25%	7¢ lb. & 60%[a, c]
Salt (*see* Sodium chloride)			
Salt cake, crude	$1 ton	Free	Free

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS (*Continued*)

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Santonin, & salts	50¢ lb. (80% & over) 25% (n.e.) (to 80%)	Free	75¢ lb.
Satin white (calcium sulfate)	½¢ lb. or 20%	10-20%	½¢ lb.
Selenium, & salts	Free	Free	Free
Siennas, crude	⅛¢ lb.	5%	⅛¢ lb.
ground	⅛-1¢ lb.	5%	⅜¢ lb.
Silica, crude, n.s.p.f.	—	—	$4 ton
for pigments	—	—	$7.50 ton
Silicon	20%	10%	8¢ lb. & 15%
(*see also* Ferrosilicon)			
Silver, comp. & mixt.	25% (n.e.)	10%	25%
German or nickel, umfd.	25%	15%	20%
salts	—	15%	—
Soapstone, crude	Free	Free	¼¢ lb.
ground	1¢ lb. or 20%	15%	25%
Sodium arsenate	1¢ lb.	Free	1¢ lb.
benzoate	25% (n.e.)	5¢ lb.	7¢ lb. & 60%[a, c]
bicarbonate	⅝¢ lb.	¼¢ lb.	¼¢ lb.
bichromate	1¾¢ lb.	¾¢ lb.	1¾¢ lb.
bisulfite, metabisulfite	25%	¼¢ lb.	⅜¢ lb.
borate, crude (borax)	2¢ lb.	Free	Free
ref.	2¢ lb.	⅛¢ lb.	⅛¢ lb.
bromide	25%	15%	10¢ lb.
carbonate, calc. (soda ash)	¼¢ lb.	Free	¼¢ lb.
hydrated (sal soda)	⅙-¼¢ lb.	⅛¢ lb.	¼¢ lb.
monohydrated (crystal)	¼¢ lb.	⅛¢ lb.	¼¢ lb.
chlorate	1½¢ lb.	½¢ lb.	1½¢ lb.
chloride (bags, sacks, bbl.)	11¢ cwt.	Free	11¢ cwt.
bulk	7¢ cwt.	Free	7¢ cwt.
chromate	1¾¢ lb.	¾¢ lb.	1¾¢ lb.
cyanide	25%	Free	Free
ferrocyanide	2¢ lb.	¾¢ lb.	2¢ lb.
formate	25%	15%	2¢ lb.
hydrosulfite, & comp.	25%	15%	35%
hydroxide (caustic soda)	½¢ lb.	¼¢ lb.	½¢ lb.
hyposulfite	⅜¢ lb.	¼¢ lb.	—
nitrate	Free	Free	Free
nitrite	2¢ lb.	½¢ lb.	3¢ lb.
phosphate	25%	¼¢ lb.	½¢ lb.
-potassium tartrate (Rochelle salt)	3¢ lb.	2½¢ lb.	5¢ lb.
sesquicarbonate	¼¢ lb.	⅛¢ lb.	¼¢ lb.
silicate	⅜¢ lb.	Free	⅜¢ lb.
sulfate, anhyd.	$1 ton	15%	$2 ton
crude (salt cake, niter cake)	$1 ton	Free	Free
cryst. (Glauber's salt)	$1 ton	$1 ton	$1 ton
sulfide, to 35% Na_2S	⅜¢ lb.	¼¢ lb.	⅜¢ lb.
35% & over	¾¢ lb.	¼¢ lb.	¾¢ lb.

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Sodium sulfite	25%	¼¢ lb.	⅜¢ lb.
sulfoxylate	25%	15%	35%
thiosulfate	⅜¢ lb.	¼¢ lb.	⅜¢ lb.
Sorbite	25%	15%	50%
Strontium carbonate, precip.	25%	15%	25%
nitrate	25%	15%	25%
oxide	Free	Free	25%
Strychnine, & salts	15¢ oz.	Free	15¢ oz.
Sulfur	Free	Free	Free
d-Tagatose & *d*-talose	25%	15%	50%
Talc, crude	Free	Free	¼¢ lb.
ground	1¢ lb. or 20%	15%	25%
Tanning materials, synth. (*see also* Dyeing & tanning)	20%	15%	7¢ lb. & 60%[a, c]
Tantalum, & nonferrous alloys	20-25%	15%	40%
Tartar (*see* Argols)			
Tartar emetic (potassium-antimony tartrate)	25%	25%	6¢ lb.
Terpin hydrate	25% (n.e.)	25%	35%
Terpineol	25%	20%	45%
Tetrachloroethane	25%	15%	35%
Tetramethyldiaminobenzophenone & tetramethyldiaminodiphenylmethane	20%	15%	7¢ lb. & 55%[a, c]
Thiocarbanilide	20%	15%	7¢ lb. & 55%[a, b]
Thorium, ore	4¢ lb.	25%	Free
salts	40%	25%	35%
Thymol	25% (n.e.)	25%	35%
Tin, & salts, comp., mixt.	25%	10%	25%
Titanium	20-25%	15%	25%
salts, comp., mixt.	25%	15%	30%
TNT	2-4¢ lb.	Free	7¢ lb. & 60%[a, c]
Tolidine	Free	10%	7¢ lb. & 55%[a, b]
Toluene	Free	5%	Free
Toluenesulfochloride & -sulfonamide	20%	15%	7¢ lb. & 55%[a, b]
Toluidine	Free	10%	7¢ lb. & 55%[a, b]
Tolylenediamine	20%	15%	7¢ lb. & 55%[a, b]
Tribromophenol	20%	15%	7¢ lb. & 55%[a, b]
Trichloroethylene	25%	15%	35%
Trinitrophenol	Free	15%	7¢ lb. & 60%[a, c]
Trinitrotoluene (TNT)	2-4¢ lb.	Free	7¢ lb. & 60%[a, c]
Tungsten, & ferroalloys, comp., n.s.p.f.	20-25%	15%	60¢ lb. & 25%
ore	10%	Free	45¢ lb.
Turpentine, gum & spirits	Free	Free	Free
Ultramarine blue	3¢ lb.	15%	3¢ lb.

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS (*Continued*)

	Payne-Aldrich Act, 1909	*Underwood Act, 1913*	*Fordney-McCumber Act, 1922*
Umber, crude	⅛¢ lb.	5%	⅛¢ lb.
ground	⅛-1¢ lb.	5%	⅜¢ lb.
Uranium, oxide & salts	Free	Free	Free
Urea	25% (n.e.)	25%	35%
Vanillin	20¢ oz.	10¢ oz.	45%
Vermilion reds, with Hg	10¢ lb.	15%	28¢ lb.
without Hg, but with Pb	4⅞¢ lb.	25%	30%
White lead	2½¢ lb.	25%	2½¢ lb.
Whiting (*see* Chalk)			
Wine lees (*see* Argols)			
Xylene	Free	5%	Free
Xylidine	Free	10%	7¢ lb. & 55%[a, b]
Xylose	25%	15%	50%
Zinc, blocks, pigs, dust	1⅜¢ lb.	15%	1¾¢ lb.
ore, to 10% Zn	Free	10%	Free
10-20%	¼¢ lb.	10%	½¢ lb.
20-25%	½¢ lb.	10%	1¢ lb.
25% & over	1¢ lb.	10%	1½¢ lb.
Zinc chloride	1¢ lb.	½¢ lb.	1 3/10¢ lb.
oxide & leaded oxides (to 25% Pb), dry	1-2½¢ lb.	10-15%	1¾¢ lb.
in oil or water	1¾-2½¢ lb.	15-25%	2¼¢ lb.
sulfate	1¢ lb.	½¢ lb.	¾¢ lb.
sulfide	1¼¢ lb.	15%	1½¢ lb.

---

[a] Based on Am. selling price of competitive U. S. article, if none, on U. S. value; [b] 7¢ & 40% after 2 yr., Special Duty Act, 1916; [c] 7¢ & 45% after 2 yr., Special Duty Act, 1916; n.e., not enumerated, but rate fixed by ruling; n.s.p.f., not specially provided for.

Appendix VI

THE COUNCIL OF NATIONAL DEFENSE, CREATED BY THE ARMY APPROPRIATION ACT *

Sec. 2. That a Council of National Defense is hereby established for the coordination of industries and resources for the national security and welfare, to consist of the Secretary of War, the Secretary of the Navy, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Commerce, and the Secretary of Labor.

That the Council of National Defense shall nominate to the President, and the President shall appoint, an advisory commission, consisting of not more than seven persons, each of whom shall have special knowledge of some industry, public utility, or the development of some natural resource, or be otherwise specially qualified, in the opinion of the council, for the performance of the duties hereinafter provided. The members of the advisory commission shall serve without compensation, but shall be allowed actual expenses of travel and subsistence when attending meetings of the commission or engaged in investigations pertaining to its activities. The advisory commission shall hold such meetings as shall be called by the council or be provided by the rules and regulations adopted by the council for the conduct of its work.

---

*Approved Aug. 29, 1916.

That it shall be the duty of the Council of National Defense to supervise and direct investigations and make recommendations to the President and the heads of executive departments as to the location of railroads with reference to the frontier of the United States, so as to render possible expeditious concentration of troops and supplies to points of defense; the coordination of military, industrial, and commercial purposes in the location of extensive highways and branch lines of railroad; the utilization of waterways; the mobilization of military and naval resources for defense; the increase of domestic production of articles and materials essential to the support of armies and of the people during the interruption of foreign commerce; the development of seagoing transportation; data as to amounts, location, method, and means of production, and availability of military supplies; the giving of information to producers and manufacturers as to the class of supplies needed by the military and other services of the Government, the requirements relating thereto, and the creation of relations which will render possible in time of need the immediate concentration and utilization of the resources of the Nation.

That the Council of National Defense shall adopt rules and regulations for the conduct of its work, which rules and regulations shall be subject to the approval of the President, and shall provide for the work of the advisory commission, to the end that the special knowledge of such commission may be developed by suitable investigation, research, and inquiry and made available in conference and report for the use of the council; and the council may organize subordinate bodies for its assistance in special investigations, either by the employment of experts or by the creation of committees of specially qualified persons to serve without compensation, but to direct the investigations of experts so employed.

That the sum of $200,000, or so much thereof as may be necessary, is hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be immediately available for experimental work and investigations undertaken by the council, by the advisory commission, or subordinate bodies, for the employment of a director, expert and clerical expenses and supplies, and for the necessary expenses of members of the advisory commission or subordinate bodies going to and attending meetings of the commission or subordinate bodies. Reports shall be submitted by all subordinate bodies and by the advisory commission to the council, and from time to time the council shall report to the President or to the heads of executive departments upon special inquiries or subjects appropriate thereto, and an annual report to the Congress shall be submitted through the President, including as full a statement of the activities of the council and the agencies subordinate to it as is consistent with the public interest, including an itemized account of the expenditures made by the council or authorized by it, in as full detail as the public interest will permit: *Provided*, *however*, That when deemed proper the President may authorize, in amounts stipulated by him, unvouchered expenditures and report the gross sum so authorized not itemized.

Appendix VII

COMMITTEES COOPERATING WITH MR. BARUCH IN THE ADVISORY COMMISSION, COUNCIL OF NATIONAL DEFENSE *

Cooperative Committee on Alcohol

Horatio S. Rubens, U. S. Industrial Alcohol Co., *chairman*
Julius Kessler, Distillers Securities Corp.
Carman N. Smith, Michigan Chemical Co.

Cooperative Committee on Asbestos, Magnesia & Roofing

Thos. F. Manville, H. W. Johns-Manville Co., *chairman*
Philip Allen, Bird & Son

---

* See *Chemical Alliance*, p. 10; Council of National Defense, *1st Ann. Rept.;* and E. R. Weidlein, *J. Ind. Eng. Chem. 11*, 1006 (1919). The Council Rept., which gives membership as of June 30, 1917, lists 21 additional committees which have been omitted.

Cooperative Committee on Chemicals

Dr. Wm. H. Nichols, General Chemical Co., *chairman*
Maj. J. T. Crabbs, Army (ret.), asst. to chairman
J. D. C. Bradley, American Agricultural Chemical Co., sec'y
Dr. M. T. Bogert, Nat. Res. Council, ex-officio
Van H. Manning, Bur. Mines, ex-officio
C. A. Richards, Dept. Com., ex-officio

Subcommittee on Acids

E. R. Grasselli, Grasselli Chemical Co., *chairman*
W. H. Cocke, Commercial Acid Co.
S. B. Fleming, International Agricultural Corp.
J. M. Goetchius, General Chemical Co.
Henry Howard, Merrimac Chemical Co.
C. Wilbur Miller, Davison Chemical Co.

Subcommittee on Alkalies

J. D. Pennock, Solvay Process Co., *chairman*
Edward E. Arnold, Mathieson Alkali Works
T. N. Hicks, Niagara Alkali Co.
Chas. H. MacDowell, Armour Fertilizer Works

Subcommittee on Coal-Tar By-Products

Wm. H. Childs, Barrett Co., *chairman*
W. R. Addicks, Consolidated Gas Co.
W. H. Gartley, United Gas Improvement Co.
H. H. S. Handy, Solvay Process Co.
Chas. J. Ramsburg, H. Koppers Co.
J. A. Topping, Republic Iron & Steel Co.

Subcommittee on Electrochemicals

John J. Riker, E. D. & J. J. Riker Co., *chairman*
E. D. Kingsley, Niagara Alkali Co.
F. A. Lidbury, Oldbury Electro-Chemical Co.
Frank J. Tone, Carborundum Co.

Subcommittee on Fertilizers

Horace Bowker, American Agricultural Chemical Co., *chairman*
Chas. F. Burroughs, F. S. Royster Guano Co.
Porter Fleming, Southern States Phosphate & Fertilizer Co.
S. B. Fleming, International Agricultural Corp.
Warner D. Huntington, Davison Chemical Co.
Chas. H. MacDowell, Armour Fertilizer Works
Wm. Prescott, American Agricultural Chemical Co.
Frederick Rayfield, Swift & Co.
A. C. Read, Read Phosphate Co.
C. G. Wilson, Virginia-Carolina Chemical Co.

Subcommittee on Miscellaneous Chemicals

Edward Mallinckrodt, Jr., Mallinckrodt Chemical Works, *chairman*
Geo. P. Adamson, General Chemical Co.
Adolph G. Rosengarten, Powers-Weightman-Rosengarten Co.

Subcommittee on Phosphate Rock

C. G. Memminger, Coronet Phosphate Co., *chairman*

Subcommittee on Domestic Pyrites

Chas. H. MacDowell, Armour Fertilizer Works, *chairman*
A. D. Ledoux, Pyrites Co., Ltd.
Wm. H. Mills, Naylor & Co., Inc.
H. P. Nash, Ladenburg, Thalmann Co.

Subcommittee on Foreign Pyrites

A. D. Ledoux, Pyrites Co., Ltd., *chairman*
Horace Bowker, American Agricultural Chemical Co.
Chas. F. Burroughs, F. S. Royster Guano Co.
Henry Howard, Merrimac Chemical Co.
Dr. Wm. H. Nichols, General Chemical Co.

Subcommittee on Sulfur

Henry Whiton, Union Sulphur Co., *chairman*

Subcommittee on Synthetic Phenol

Herbert H. Dow, Dow Chemical Co., *chairman*
W. A. Bradford, Butterworth-Judson Corp.
Capt. W. E. McKay, New England Fuel & Transportation Co.

Cooperative Committee on Copper

J. D. Ryan, Anaconda Copper Mining Co., *chairman*
R. L. Agassiz, Calumet & Hecla Mining Co.
W. A. Clark, United Verde Copper Co.
Murry M. Guggenheim, N. Y. City
James McLean, Phelps Dodge Corp.

Cooperative Committee on Lead

Clinton H. Crane, St. Joseph Lead Co., *chairman*
Fred Bradley, Bunker Hill & Sullivan Mining & Concentrating Co.
E. W. P. Brush, American Smelting & Refining Co.
E. J. Cornish, National Lead Co.
Harry L. Day, Hercules Mining Co.
F. Y. Robertson, U. S. Metals Refining Co.

Cooperative Committee on Zinc

Edgar Palmer, New Jersey Zinc Co., *chairman*
Chas. W. Baker, American Zinc, Lead & Smelting Co.
A. P. Cobb, New Jersey Zinc Co.
Sidney J. Jennings, U. S. Smelting, Refining & Mining Co.
Cornelius F. Kelley, Anaconda Copper Mining Co.
N. Bruce MacKelvie, Butte & Superior Copper Co.
Thos. F. Noon, Illinois Zinc Co.
Chas. T. Orr, Bertha A. Mining Co.

Appendix VIII

WAR SERVICE COMMITTEES OF THE U. S. CHAMBER OF COMMERCE AND THEIR MEMBERS *

Chemicals

Central Committee

Horace Bowker, American Agricultural Chemical Co., *chairman*
J. D. C. Bradley, American Agricultural Chemical Co.
Wm. H. Childs, Barrett Co.
E. R. Grasselli, Grasselli Chemical Co.
Henry Howard, Merrimac Chemical Co.
W. D. Huntington, Davison Chemical Co.
D. W. Jayne, Barrett Co.
A. D. Ledoux, Pyrites Co., Ltd.
F. A. Lidbury, Oldbury Electro-Chemical Co.
Chas. H. MacDowell, Armour Fertilizer Works
Edward Mallinckrodt, Jr., Mallinckrodt Chemical Works
Wm. H. Nichols, General Chemical Co.
J. D. Pennock, Solvay Process Co.
C. L. Reese, E. I. du Pont de Nemours & Co.
John J. Riker, E. D. & J. J. Riker Co.
A. G. Rosengarten, Powers-Weightman-Rosengarten Co.
C. G. Wilson, Virginia-Carolina Chemical Co.

Acids

W. D. Huntington, Davison Chemical Co., *chairman*
C. F. Burroughs, F. S. Royster Guano Co.
Chas. M. Butterworth, Pennsylvania Salt Mfg. Co.
S. B. Fleming, International Agricultural Corp.
J. M. Goetchius, General Chemical Co.
J. H. D. Rodier, Grasselli Chemical Co.

Alkalies

J. D. Pennock, Solvay Process Co., *chairman*
N. E. Bartlett, Pennsylvania Salt Mfg. Co.
E. H. Hooker, Hooker Electrochemical Co.
E. M. Sergeant, Niagara Alkali Co.

Coal-Tar By-Products

D. W. Jayne, Barrett Co., *chairman*
W. R. Addicks, Consolidated Gas Co.
W. E. McKay, New England Fuel & Transportation Co.
C. J. Ramsburg, H. Koppers Co.
A. A. Schlesinger, Milwaukee Coke & Gas Co.

Dyestuffs

C. L. Reese, E. I. du Pont de Nemours & Co., *chairman*
A. R. Curtin
F. M. Fargo, Calco Chemical Co.
R. W. Hochstetter, Ault & Wiborg Co.

---

* There were 168 committees in all. Only those of chemical interest are listed here. See Clarkson, *Industrial America in World War*, pp. 532-43.

J. M. Matthews, Grasselli Chemical Co.
August Merz, Heller & Merz Co.
H. A. Metz, Central Dyestuff & Chemical Co.
M. R. Poucher, E. I. du Pont de Nemours & Co.
H. D. Ruhm, Ruhm Phosphate & Chemical Co.
I. F. Stone, National Aniline & Chemical Co.

Electrochemicals

F. A. Lidbury, Oldbury Electro-Chemical Co., *chairman*
C. D. Cohen, American Cyanamid Co.
F. J. Tone, Carborundum Co.

Fertilizers

C. G. Wilson, Virginia-Carolina Chemical Co., *chairman*
C. F. Burroughs, F. S. Royster Guano Co.
Porter Fleming, Southern States Phosphate & Fertilizer Co.
Albert French, International Agricultural Corp.
W. D. Huntington, Davison Chemical Co.
C. H. MacDowell, Armour Fertilizer Works
Wm. Prescott, American Agricultural Chemical Co.
Frederick Rayfield, Swift & Co.
A. C. Read, Read Phosphate Co.

Miscellaneous Chemicals

A. G. Rosengarten, Powers-Weightman-Rosengarten Co., *chairman*
G. P. Adamson, General Chemical Co.
Wm. H. Bower, Henry Bower Chemical Mfg. Co.

Foreign Pyrites

A. D. Ledoux, Pyrites Co., Ltd., *chairman*
C. F. Burroughs, F. S. Royster Guano Co.
W. H. Mills, Naylor & Co., Inc.
W. H. Nichols, General Chemical Co.

Domestic Pyrites & Sulfur

C. H. MacDowell, Armour Fertilizer Works, *chairman*
H. P. Nash, Ladenburg, Thalmann Co.
W. N. Wilkinson, Union Sulphur Co.
C. G. Wilson, Virginia-Carolina Chemical Co.

Drugs

Willard Ohliger, F. Stearns & Co., *chairman*
Dr. W. C. Abbott, Abbott Labs.
Burton T. Bush, Antoine Chiris Co.
Milton Campbell, H. K. Mulford Co.
Dr. H. C. Lovis, Seabury & Johnson
Donald McKesson, McKesson & Robbins
Frederic Rosengarten, Powers-Weightman-Rosengarten Co.
Frank G. Ryan, Parke, Davis & Co.
W. A. Sailer, Sharp & Dohme

Proprietary Drugs

Frank A. Blair, Foley & Co., *chairman*
A. H. Beardsley, Dr. Miles Medical Co.
E. K. Hyde, Mentholatum Co.
Louis K. Liggett, United Drug Co.
Z. C. Patten, Jr., Chattanooga Medicine Co.
W. E. Weiss, Drug, Inc

Lithopone

A. S. Krebs, Krebs Pigment & Chemical Co., *chairman*
F. S. Havens, Atlantic Products Corp.
P. S. Tilden, E. I. du Pont de Nemours & Co.

Wood Chemicals

John Troy, Heinemann Chemical Co., *chairman*
F. E. Clawson, Clawson Chemical Co.
H. E. Gaffney, Gaffney Bros

Appendix IX

LETTER APPOINTING BARUCH CHAIRMAN OF THE WAR INDUSTRIES BOARD *

The White House,
Washington, March 4, 1918.

My dear Mr. Baruch: I am writing to ask if you will not accept appointment as Chairman of the War Industries Board, and I am going to take the liberty at the same time of outlining the functions, the constitution and action of the Board as I think they should now be established.

The functions of the Board should be:

(1) The creation of new facilities and the disclosing, if necessary, the opening up of new or additional sources of supply;

(2) The conversion of existing facilities, where necessary, to new uses;

(3) The studious conservation of resources and facilities by scientific, commercial, and industrial economies;

(4) Advice to the several purchasing agencies of the Government with regard to the prices to be paid;

(5) The determination, wherever necessary, of priorities of production and of delivery and of the proportions of any given article to be made immediately accessible to the several purchasing agencies when the supply of that article is insufficient, either temporarily or permanently;

(6) The making of purchases for the Allies.

The Board should be constituted as at present and should retain, so far as necessary and so far as consistent with the character and purposes of the reorganization, its present advisory agency; but the ultimate decision of all questions, except the determination of prices, should rest always with the Chairman, the other members acting in a cooperative and advisory capacity. The further organization of advice I will indicate below.

In the determination of priorities of production, when it is not possible to have the full supply of any article that is needed produced at once, the Chairman should be assisted, and so far as practicable, guided by the present priorities organization or its equivalent.

In the determination of priorities of delivery, when they must be determined, he should be assisted when necessary, in addition to the present advisory priorities organization, by the advice and cooperation of a committee constituted for the purpose and consisting of official representatives of the Food Administration, the Fuel Administration, the Railway Administration, the Shipping Board, and the War Trade Board, in order that when a priority of delivery has been determined there may be common, consistent, and concerted action to carry it into effect.

In the determination of prices the Chairman should be governed by the advice of a committee consisting, besides himself, of the members of the Board immediately charged with the study of raw materials and of manufactured products, of the labor member of the Board, of the Chairman of the Federal Trade Commission, the Chairman of the Tariff Commission, and the Fuel Administrator.

The Chairman should be constantly and systematically informed of all contracts, purchases, and deliveries, in order that he may have always before him a schematized analysis of the progress of business in the several supply divisions of the Government in all departments.

The duties of the Chairman are:

(1) To act for the joint and several benefit of all the supply departments of the Government.

(2) To let alone what is being successfully done and interfere as little as possible with the present normal processes of purchase and delivery in the several departments.

(3) To guide and assist wherever the need for guidance or assistance may be revealed; for example, in the allocation of contracts, in obtaining access to materials in any way preempted, or in the disclosure of sources of supply.

(4) To determine what is to be done when there is any competitive or other conflict of interest between departments in the matter of supplies; for example, when there is not a sufficient imme-

---

* See Baruch, *American Industry in the War*, p. 24.

diate supply for all and there must be a decision as to priority of need or delivery, or when there is competition for the same source of manufacture or supply, or when contracts have not been placed in such a way as to get advantage of the full productive capacity of the country.

(5) To see that contracts and deliveries are followed up where such assistance as is indicated under (3) and (4) above has proved to be necessary.

(6) To anticipate the prospective needs of the several supply departments of the Government and their feasible adjustment to the industry of the country as far in advance as possible, in order that as definite an outlook and opportunity for planning as possible may be afforded the business men of the country.

In brief, he should act as the general eye of all supply departments in the field of industry.

Cordially and sincerely yours,

Woodrow Wilson

Mr. Bernard M. Baruch,
Washington, D. C.

Appendix X

THE WAR INDUSTRIES BOARD *

The Board

Bernard M. Baruch, chairman, ex-officio member of all committees; *Alexander Legge*, International Harvester Co., vice-chairman; *Rear Adm. Frank F. Fletcher*, Navy; *Maj. Gen. Geo. W. Goethals*, Army; *Robt. S. Brookings*, Washington U., Price-Fixing Committee; *Hugh Frayne*, A. F. of L., labor; *Edwin B. Parker*, Baker, Botts, Parker & Garwood, priorities commissioner; *Geo. N. Peek*, Deere & Co., commissioner of finished products; *J. Leonard Replogle*, American Vanadium Co., steel administrator; *Leland L. Summers*, L. L. Summers & Co., technical advisor; *Albert C. Ritchie*, attorney general of Md., general counsel; *Howard P. Ingles*, Realty Guaranty & Trust Co., sec'y; *Herbert B. Swope*, N. Y. World, assoc.; *Clarence Dillon*, Wm. A. Reed & Co., asst. to chairman; *Harrison Williams*, asst. to chairman; *Harold T. Clark*, Squire, Sanders & Dempsey, asst. to chairman.

Price-Fixing Committee

Robt. S. Brookings, Washington U., chairman; *Bernard M. Baruch; W. B. Colver*, chairman, Fed. Trade Comm.; *Hugh Frayne*, labor; *Dr. H. A. Garfield*, chairman, Fuel Admin., *Com. John M. Hancock*, Navy; *Lt. Col. Robt. H. Montgomery*, Lybrand-Ross Bros. & Montgomery, Army; *Henry C. Stuart*, ex-Gov. of Va.; *Dr. F. W. Taussig*, chairman, Tariff Comm.; *Wm. W. Phelps*, Wm. W. Phelps estate, Inc., sec'y.

Allied Purchasing Commission

Bernard M. Baruch; Robt. S. Lovett, priorities commissioner (ret.); *Robt. S. Brookings*, Price-Fixing Comm.; *Alexander Legge*, International Harvester Co., business mgr.; *James A. Carr*, American Seeding Machine Co., successor to Mr. Legge; *A. L. Bostwick*, Planning Comm. St. Louis, asst.; *James C. Leddy*, Armour & Co., asst.; *Frank E. Penick*, International Harvester Co., asst.

Requirements Division

Alexander Legge, International Harvester Co., chairman; *Lt. Col. C. C. Bolton*, Bourne Fuller Co., General Staff; *Geo. M. Brill*, Emergency Fleet; *James A. Carr*, American Seeding Machine Co., the Allies; *Col. Geo. H. Estes*, Army; *James Inglis*, American Blower Co.; *Chas. H. MacDowell*, Armour Fertilizer Works, chemicals; *P. B. Noyes*, Fuel Admin.; *Edwin B. Parker*, Baker, Botts, Parker & Garwood, priorities; *Geo. N. Peek*, Deere & Co., finished products; *Adm. C. J. Peoples*, Navy; *M. B. Pool*, Red Cross; *Thos. C. Powell*, Southern Ry. Co., Railroad Admin.; *J. Leonard Replogle*, American Vanadium Co., steel; *A. W. Shaw*, A. W. Shaw Co., conservation; *L. L.*

---

* See Clarkson, *Industrial America in World War*, pp. 501-531, for complete roster.

Summers, L. L. Summers & Co.; *Capt. M. N. Taylor*, Ordnance Bur., Navy; *T. F. Whitmarsh*, Francis H. Liggett Co., Food Admin.; *Maj. Seth Williams*, Marine Corps; *Pope Yeatman*, non-ferrous metals; *W. E. Guylee*, Cable Piano Co., exec. sec'y.

Clearance Office: *James C. Musser*, Musser, Kimber, Huffman & Musser, sec'y; *Claire B. Hughes*, Marshall & Fraser, asst. sec'y.

Priorities Division

Edwin B. Parker, Baker, Botts, Parker & Garwood, priorities commissioner; *Rhodes S. Baker*, Thompson, Knight, Baker & Harris, asst. priorities commissioner.

Priorities Board: *Edwin B. Parker; Edward Chambers*, Railroad Admin., dir. traffic; *Rear Adm. Frank F. Fletcher*, Navy; *Felix Frankfurter*, Labor Dept., labor; *Gen. Geo. W. Goethals*, Army; *Alexander Legge*, International Harvester Co., Allied Purchasing Comm.; *P. B. Noyes*, Fuel Admin., dir. conservation; *T. F. Whitmarsh*, Francis H. Liggett Co., Food Admin.; *Chas. R. Piez*, Emergency Fleet & Shipping Bd.; *Clarence M. Wooley*, American Radiator Co., War Trade Bd.; *Henry G. Phillipps*, American Bottle Co., sec'y.

Priorities Committee: *Edwin B. Parker*, Baker, Botts, Parker & Garwood, chairman; *Chas. K. Foster*, American Radiator Co., vice-chairman; *Geo. N. Armsby*, California Packing Corp.; *Henry H. Barbour*, Lackawanna Steel Co.; *Wendell W. Chase; Percy Holbrook*, Rail Joint Co.; *James M. Hopkins*, Camol Co.; *Henry Krumb; Frank H. Macpherson*, Detroit Sulphite Pulp & Paper Co.; *Rear Adm. Newton E. Mason*, Navy; *Lt. Col. Chas. A. McKenney*, Army; *Everett Morss*, Morss & White Co.; *Lucius P. Ordway*, Crane-Ordway Co.; *Thos. C. Powell*, Southern Ry. Co.; *Rear Adm. A. V. Zane* (ret.); *Maurice Hirsch*, sec'y; *Marcus B. Hall*, American Box Board Co., asst. sec'y.

Labor Section: *A. W. Clapp*, chief.

Non-War Construction Section: *Donald R. McLennan*, Marsh & McLennan, chief.

Conservation Division

A. W. Shaw, A. W. Shaw Co., chairman; *Chas. K. Foster*, American Radiator Co.; *Dr. Edwin F. Gay*, Harvard U.; *Lt. Col. W. R. Roberts; Chas. H. MacDowell*, Armour Fertilizer Works; *Rear Adm. Samuel McGowan*, Navy; *Geo. N. Peek*, Deere & Co.; *Thos. C. Powell*, Southern Ry. Co.; *Pope Yeatman; Melvin T. Copeland*, Harvard U., exec. sec'y.

Division of Planning & Statistics

Edwin F. Gay, Harvard U., chairman; *Henry S. Dennison*, Dennison Mfg. Co., asst. chairman; *Henry R. Hatfield*, U. Calif., dir.; *John L. Coulter*, U. West Va., chief, commodity section; *Dr. Wesley C. Mitchell*, Columbia U., chief, price section; *Mills E. Case*, chief, contract section; *Leo Wolman*, Johns Hopkins U., ed. of CommodityBull.; *Wm. A. Barber*, N. Y. U.; *Alice C. Boughton*, Bur. Educ. Exp.; *Stuart Daggett*, U. Calif.; *Lawrence K. Frank*, N. Y. Telephone Co.; *Paul W. Garrett*, Bur. State Research, Newark; *Walter Holsinger; Walter W. Stewart*, Amherst Coll.

Chemicals Division

Chas. H. MacDowell, Armour Fertilizer Works, dir.; *Richard L. Wood*, Richard L. Wood Co., *Chas. E. Sholes*, assts.

Acids & Heavy Chemicals Section: *Albert R. Brunker*, Liquid Carbonic Co., chief; *Russell S. Hubbard*, Harrison Bros., assoc.; *Arthur E. Wells*, Bur. Mines, assoc.

Alkali & Chlorine Section: *Horace G. Carrell*, Solvay Process Co., chief; *John F. Tim*, assoc. chief; *Lt. Edward A. Williams*, Starkweather, Williams & Co., assoc.

Artificial Dyes & Intermediates Section: *Dr. Victor L. King*, chief; *Dr. J. F. Schoellkopf, Jr.*, National Aniline & Chemical Co., chief (resigned).

Asbestos & Magnesia Section: *Robt. M. Torrence*, Highland Glass Co., chief.

Chemical Glass & Stoneware Section: *Robt. M. Torrence*, Highland Glass Co., chief.

Creosote Section: *Ira C. Darling*, Bartholomay & Darling, chief.

Electrodes & Abrasives Section: *Capt. Henry C. DuBois*, E. J. Lavino & Co., chief.

Ethyl Alcohol Section: *Wm. G. Woolfolk*, Sanderson & Porter, chief; *Arthur E. Wells*, Bur. Mines, assoc.

Ferroalloys Section: ***Hugh W. Sanford,*** **Sanford-Day Iron Works, chief;** ***Chester D. Tripp,*** Miami Metals Co., assoc.

Industrial Gases & Gas Products Section: *Maj. John M. Morehead,* Union Carbide & Carbon Corp.; *Ira C. Darling,* Bartholomay & Darling, assoc.

Mica Section: *C. K. Leith,* U. Wis., chief.

Miscellaneous Chemicals Section: *A. G. Rosengarten,* Powers-Weigntman-Rosengarten Co., chief.

Nitrate of Soda Section: *Chas. H. MacDowell,* Armour Fertilizer Works, chief; *John A. Becker,* Armour Fertilizer Works, assoc.; *H. Ray Paige,* H. Ray Paige & Co.

Paint & Pigment Section: *Lewis R. Atwood,* Peaslee-Gaulbert Co., chief; *Russell S. Hubbard,* Harrison Bros. & Co., chief (deceased); *James E. Patton,* assoc. chief.

Platinum Section: *Chas. H. Conner,* Kissel, Kinnicut & Co., chief; *R. H. Carleton,* Blodgett & Co., assoc.; *Geo. E. DeNike,* Graves, Maubert, George & Co., assoc.

Refractories Section: *Chas. Catlett,* chief.

Sulfur & Pyrites Section: *Wm. G. Woolfolk,* Sanderson & Porter, chief; *Arthur E. Wells,* Bur. Mines, assoc.; *John R. Townsend,* Sanderson & Porter, assoc.

Tanning Materials & Natural Dyes Section: *Edwin J. Haley,* Haley-Hammond Co., chief; *E. A. Prosser,* Borne Scrymser Co., assoc.; *Harold G. Wood,* Forest Serv., assoc.

Technical & Consulting Section: *Dr. Herbert R. Moody,* N. Y. C. Coll., chief; *Dr. M. T. Bogert,* Columbia U., chief (resigned); *Dr. S. A. Tucker,* Chandler Museum, assoc.; *Dr. E. R. Weidlein,* Mellon Inst., assoc.; *Dr. Thos. P. McCutcheon,* U. Penn., assoc.

Wood Chemicals Section: *Chas. H. Conner,* Kissel, Kinnicut & Co., chief; *Arthur H. Smith,* Wm. S. Gray & Co., assoc.; *Reginald D. Walker,* L. J. Husted Co., assoc.

Electrical & Power Equipment Section

Walter Robbins, Wagner Electric & Mfg. Co., chief; *L. W. Grothaus,* Allis Chalmers Mfg. Co.; *John H. Waterman,* Allis Chalmers Mfg. Co.; *Allan P. Bender,* Westinghouse Electric & Mfg. Co.; *Max Greenburg,* Worthington Pump & Machine Co.; *Merritt Mc.Hughes,* General Electric Co.; *Wm. S. James,* Crouse-Hinds Co.; *Thos. S. Knight,* General Electric Co.; *Edward R. Welles,* J. A. White & Co.; *John A. Merwin,* Burke Electric Co.

Explosives Division

March F. Chase, Commercial Acid Co., chief.

Gold & Silver Section

Chas. H. Conner, Kissel, Kinnicut & Co., chief.

Joint Office on Chemical Statistics

Capt. Willis B. Rice, Duell, Warfield & Duell, assoc.; *Lt. M. R. Gordon,* National City Bank, assoc.; *Lt. Ray P. Dunning,* assoc.; *Arthur Minnick,* Patent Off., assoc.

Medical Section

Lt. Col. F. F. Simpson, chief; *David L. Kean,* Chas. Lentz & Sons; *A. G. Rosengarten,* Powers-Weightman-Rosengarten Co., medical chemicals.

Nonferrous Metals Section

Pope Yeatman, chief; *E. C. Thurston,* asst.; *Andrew Walz,* Guggenheim Bros., asst.; *Irwin H. Cornell,* St. Joseph Lead Co., lead and zinc.

Optical Glass & Instruments Section

Geo. E. Chatillon, John Chatillon & Sons, chief; *Maj. F. E. Wright,* Army; *Lt. Com. H. A. Orr,* Navy.

Tin Section

Geo. N. Armsby, California Packing Corp., chief; *Lincoln Hutchinson,* U. Calif., asst.; *Thos. G. Cranwell,* Continental Can Co., asst.

Appendix XI

ORGANIZATION OF THE CHEMICALS DIVISION *

by C. H. MacDowell

When Baruch asked me to take charge of the organization of the Division I first secured the approval of Ogden Armour. I then selected James Leddy, in charge of the office setup of the company to come with me to Washington and perform a like task. When Leddy had completed this work Alex Legge asked me to let him have Leddy to work out a better organization in Allied buying of which Legge had charge. Leddy remained with the Allied Purchasing Commission during the war.

I then selected John Becker, Armour's chief auditor and assistant comptroller as office manager and to have charge of nitrate records and accounting. Becker wielded a sharp pencil. He was appointed Associate Chief of the Nitrate Section.

I selected as private secretary W. A. Barsh, who was acting in that capacity for the head of the Beef Department of Armour & Company. A skilled and very dependable chap was Barsh.

We installed immediately the subject filing system used by the Armour Fertilizer Works. Other sections of the War Industries Board were having great difficulty in filing and finding. Our system worked from the start and when the files were turned over to the War Department later they commended us highly for their complete and findable condition.

When the War Industries Board was officially formed, I completed the organization of the Joint Office of Chemical Statistics. All chemical manufacturers were being pestered by numerous Toms, Dicks, and Harrys around Washington with questionnaires, many of them duplicating and overlapping. I had Baruch's approval to set up our own shop and to advise the chemicals trade to refer all comers to the Joint Statistical Division for facts and figures. I can still hear the sigh of relief that went up from the trade. What we wanted was working statistics secured in time for use and we got them.

In the selection of section chiefs and associates we preferred young men who were not too dependent on their secretaries—"comers" we called them. We avoided the contentious type of executive and the alibi boy. It was politically wise to avoid placing men in charge of commodities who were too directly interested in their manufacture and sale.

One of the most useful facilities we developed during the war period was the two general staff meetings, held weekly in my office. These meetings—naturally closed to outsiders—were attended by the full membership of each section including the armed services. Each section chief made a report of progress and explained his problems, and it was surprising how much knowledge and good advice came from members of other sections. These meetings, which were highly educational and informative, became quite a feature in War Industries Board doings and were visited by higher-ups who could give the countersign.

We also held meetings with industries to explain situations and to ascertain conditions in the industry as to supply, yields, possibilities of using better methods, etc. We often suggested new ways or substitute raw materials. We suggested that some of the industries form industrial research fellowships which they did later.

Appendix XII

THE CHEMICAL ALLIANCE

OFFICERS, DIRECTORS, COMMITTEES, AND MEMBERS OF SECTIONS

Officers

Horace Bowker, American Agricultural Chemical Co., *president*
Henry Howard, Merrimac Chemical Co., *vice-president*
J. D. C. Bradley, American Agricultural Chemical Co., *secretary-treasurer*

---

* Memo to author, dated Winter Park, Fla., Nov. 23, 1940.

Directors

Horace Bowker, American Agricultural Chemical Co.
E. R. Grasselli, Grasselli Chemical Co.
A. W. Hawkes, General Chemical Co.
Henry Howard, Merrimac Chemical Co.
W. D. Huntington, Davison Chemical Co.
D. W. Jayne, Barrett Co.
A. D. Ledoux, Pyrites Co., Ltd.
F. A. Lidbury, Oldbury Electro-Chemical Co.
C. H. MacDowell, Armour Fertilizer Works
Edward Mallinckrodt, Jr., Mallinckrodt Chemical Works
W. N. McIlravy, Barrett Co.
J. D. Pennock, Solvay Process Co.
C. L. Reese, E. I. du Pont de Nemours & Co.
John J. Riker, E. D. & J. J. Riker Co.
A. G. Rosengarten, Powers-Weightman-Rosengarten Co.
C. G. Wilson, Virginia-Carolina Chemical Co.

Acids Section

W. D. Huntington, Davison Chemical Co., *chairman*
C. F. Burroughs, F. S. Royster Guano Co.
Chas. M. Butterworth, Pennsylvania Salt Mfg. Co.
S. B. Fleming, International Agricultural Corp.
A. W. Hawkes, General Chemical Co.
J. H. D. Rodier, Grasselli Chemical Co.

American Alkali & Acid Co.
American Steel & Wire Co.
American Zinc & Chemical Co.
American Zinc, Lead & Smelting Co.
Anaconda Copper Mining Co.
Atlas Powder Co.
Avery Chemical Co.
Calumet & Arizona Mining Co.
Central Chemical Co.
Cleveland-Cliffs Iron Co.
Contact Process Co.
Chas. Cooper & Co.
Davison Chemical Co.
Detroit Chemical Works
E. I. du Pont de Nemours & Co.
Farmers' Fertilizer Co.
General Chemical Co.
Grasselli Chemical Co.
Hegeler Zinc Co.
Illinois Zinc Co.
International Agricultural Corp.
Kalbfleisch Corp.
King Chemical Co.
Lambert Chemical Co.
Chas. Lennig & Co.
Matthiessen & Hegeler Zinc Co.
McCabe Chemical Co.
Merrimac Chemical Co.
Mutual Chemical Co.
National Zinc Co.
Naugatuck Chemical Co.
New Jersey Zinc Co.
Pennsylvania Salt Mfg. Co.
Pennsylvania Trojan Powder Co.
Powers-Weightman-Rosengarten Co.
Riverside Acid Works
Robinson Brothers
Stauffer Chemical Co.
Steel Cities Chemical Co.
Sugarland Mfg. Co.
Titanium Alloy Mfg. Co.
United Zinc Smelting Co.
Western Chemical Mfg. Co.

Alkalies Section

J. D. Pennock, Solvay Process Co., *chairman*
N. E. Bartlett, Pennsylvania Salt Mfg. Co.
E. H. Hooker, Hooker Electrochemical Co.
E. M. Sergeant, Niagara Alkali Co.
Eli Winkler, Columbia Chemical Co.

American Trona Corp.
Antigo Potash Co.
Bush, Beach & Gent, Inc.
Columbia Chemical Co.
Diamond Alkali Co.
Hooker Electrochemical Co.
Isco Chemical Co.
Niagara Alkali Co.
Pennsylvania Salt Mfg. Co.
Rollin Chemical Co., Inc.
Solvay Process Co.

By-Products of Coal & Gas Section

D. W. Jayne, Barrett Co., *chairman*
W. R. Addicks, Consolidated Gas Co.
W. E. McKay, New England Fuel & Transporation Co.
C. J. Ramsburg, H. Koppers Co.
A. A. Schlesinger, Milwaukee Coke & Gas Co.

Allegheny By-Product Coke Co.
Barrett Co.
Bethlehem Steel Corp.
Brier Hill Steel Co.
Chatfield Mfg. Co.
Citizens Gas Co.
U. S. Industrial Alcohol Co.
Victor Chemical Works
Warner Chemical Co.
Warner-Klipstein Chemical Co.

Disinfectants Section

A. J. Marcuse, West Disinfecting Co., *chairman*
D. W. Calkins, Rochester Germicide Co.
H. W. Cole, Barrett Co.

Baird & McGuire, Inc.
Barrett Co.
Drs. Hess & Clark
Rochester Germicide Co.
West Disinfecting Co.

Dyestuffs & Intermediates Section

C. L. Reese, E. I. du Pont de Nemours & Co., *chairman*
J. M. Matthews, Grasselli Chemical Co., *secretary*
B. R. Armour, American Aniline Products, Inc.
R. P. Dicks, Dicks, David Co.
F. M. Fargo, Calco Chemical Co.
R. W. Hilton, Ault & Wiborg Co.
August Merz, Heller & Merz Co.
H. A. Metz, Central Dyestuff & Chemical Co.
W. T. Miller, National Aniline & Chemical Co.
C. K. Simon, Dye Products & Chemical Co.

Althouse Chemical Co.
American Aniline Products, Inc.
Ault & Wiborg Co.
Calco Chemical Co.
Central Dyestuff & Chemical Co.
Chemical Co. of America
Consolidated Color & Chemical Co.
Dicks, David Co.
Dow Chemical Co.
E. I. du Pont de Nemours & Co.
Dye Products & Chemical Co.
Essex Aniline Works
Grasselli Chemical Co.
Heller & Merz Co.
Marden, Orth & Hastings Co.
Monroe Color & Chemical Co.
National Aniline & Chemical Co.
Naugatuck Chemical Co.
Newport Chemical Works, Inc.
United Piece Dye Works
Zobel Color Works

Electrochemicals Section

F. A. Lidbury, Oldbury Electro-Chemical Co., *chairman*
H. W. Kellogg, National Electrolytic Co.
W. Acheson Smith, Acheson Graphite Co.
C. E. Taylor, Taylor Chemical Co.
F. J. Tone, Carborundum Co.

Acheson Graphite Co.
American Phosphorus Co.
Carborundum Co.
National Carbon Co., Inc.
National Electrolytic Co.
North American Chemical Co.
Norton Co.
Oldbury Electro-Chemical Co.
Roessler & Hasslacher Chemical Co.
Taylor Chemical Co.
Union Carbide Co.

Fertilizers Section

C. G. Wilson, Virginia-Carolina Chemical Co., *chairman*
J. D. C. Bradley, American Agricultural Chemical Co., *assistant*
John D. Toll, National Fertilizer Assoc., *secretary*
Horace Bowker, American Agricultural Chemical Co., *ex-officio*
DeWitt Brown, Armour Fertilizer Works
C. F. Burroughs, F. S. Royster Guano Co.
Porter Fleming, Southern States Phosphate & Fertilizer Co.
Albert French, International Agricultural Corp.
W. D. Huntington, Davison Chemical Co.
Wm. Prescott, American Agricultural Chemical Co.
Frederick Rayfield, Swift & Co.
A. C. Read, Read Phosphate Co.

Acme Manufacturing Co.
A. D. Adair & McCarty Bros., Inc.
Alabama Chemical Co.
American Agricultural Chemical Co.
American Cyanamid Co.
Anderson Phosphate & Oil Co.
Arkansas Fertilizer Co.
Armour Fertilizer Works
Baltimore Fertilizer Co.
Barker Chemical Co.
Batesburg Cotton Oil Co.
Baugh Chemical Co.
Baugh & Sons Co.
Berkshire Fertilizer Co.
Caraleigh Phosphate & Fertilizer Works
Central Chemical Co.
Darling & Co.
Davison Chemical Co.
Dockwiler & Kingsbury Co.
Empire State Chemical Co.
Etiwan Fertilizer Co.
Federal Chemical Co., Inc.
Georgia Fertilizer & Oil Co.
Grasselli Chemical Co.
Griffith & Boyd Co.
Groves Fertilizer Works
Gulfport Fertilizer Co.
Home Fertilizer & Chemical Co.
Hopkins Fertilizer Co.
Hubbard Fertilizer Co.
Independent Packers' Fertilizer Co.
International Agricultural Corp.
Jackson Fertilizer Co.
Jarecki Chemical Co.
Jefferson Fertilizer Co.
Lakeland Phosphate Co.
Lancaster Chemical Co.
Lebanon Fertilizer Works
Lowell Fertilizer Co.
Mapes Formula & Peruvian Guano Co.
Meridian Fertilizer Factory
Miller Fertilizer Co.
Molony & Carter Co.
Morris Fertilizer Co.
Mutual Fertilizer Co.
G. Ober & Sons Co.
Olds & Whipple
Pacific Guano & Fertilizer Co.
Peerless Fertilizer Co.
Phosphate Mining Co.
Piedmont-Mt. Airy Guano Co.
Pittsburgh Provision & Packing Co.
Planters' Fertilizer & Phosphate Co.
Porter Fertilizer Co.
Ramsburg Fertilizer Co.
E. Rauh & Sons Fertilizer Co.
Read Phosphate Co.
Reading Bone Fertilizer Co.
Reliance Fertilizer Co.
Richmond Guano Co.
Robertson Fertilizer Co.
Rogers & Hubbard Co.
F. S. Royster Guano Co.
Schoen Brothers
Scott Fertilizer Co.
Smith Agricultural Chemical Co.
Southern Fertilizer & Chemical Co.
Southern States Phosphate & Fertilizer Co.
Swift & Co.
I. P. Thomas & Son Co.
W. B. Tilghman Co.
Tupelo Fertilizer Factory
Union Seed & Fertilizer Co.
United Chemical & Organic Products Co.

Virginia-Carolina Chemical Co.
M. E. Wheeler
Willcox, Ives & Co.
Wilson & Toomer Fertilizer Co.
Wuichet Fertilizer Co.
Wulbern Fertilizer Co.
York Chemical Works
J. R. Young Fertilizer Co., Inc.

Insecticides Section

G. R. Cushman, General Chemical Co., *chairman*
H. P. John, *secretary*
G. C. Good, Dow Chemical Co.
W. H. Rose, Interstate Chemical Co.
W. O. Tuck, Corona Chemical Co.
H. D. Whittlessey, Sherwin-Williams Co.

Bowker Insecticide Co.
California Spray Chemical Co.
Corona Chemical Co.
Devoe & Raynolds Co., Inc.
Glidden Co.
Hemingway & Co., Inc.
Morris Herrmann & Co.
Interstate Chemical Co.
Kil-Tone Co.
Latimer Chemical Co.
Mechling Bros. Mfg. Co.
Niagara Sprayer Co.
Nitrate Agencies Co., Ltd.
Riches, Piver & Co.
Sherwin-Williams Co.
Toledo Rex Spray Co.

Miscellaneous Chemicals Section

A. G. Rosengarten, Powers-Weightman-Rosengarten Co., *chairman*
G. P. Adamson, General Chemical Co.
Wm. Henry Bower, Henry Bower Chemical Mfg. Co.

Atlas Powder Co.
Henry Bower Chemical Mfg. Co.
Chas. Cooper & Co.
M. J. Corbett & Co.
Dow Chemical Co.
General Chemical Co.
Grasselli Chemical Co.
William S. Gray & Co.
Harshaw, Fuller & Goodwin Co.
H. Kohnstamm Co.
Krebs Pigment & Chemical Co.
Mallinckrodt Chemical Works
Marden, Orth & Hastings Corp.
Merck & Co.
Merrimac Chemical Co.
Monsanto Chemical Works
National Electrolytic Co.
New York Quinine & Chemical Works
Perth Amboy Chemical Works
Chas. Pfizer & Co., Inc.
Phosphorus Compounds Co.
Powers-Weightman-Rosengarten Co.
N. P. Pratt Lab.
Rollin Chemical Co., Inc.
Tartar Chemical Works
U. S. Industrial Alcohol Co.
Victor Chemical Works
Warner Chemical Co.
Warner-Klipstein Chemical Co.

Domestic Pyrites & Sulfur Section

C. H. MacDowell, Armour Fertilizer Works, *chairman*
H. P. Nash, Ladenburg, Thalmann Co.
C. A. Snider, Union Sulphur Co.
C. G. Wilson, Virginia-Carolina Chemical Co.

Bethlehem Steel Corp.
E. I. du Pont de Nemours & Co.
Augustus H. Eustis
Freeport Sulphur Co.
St. Lawrence Pyrites Co.
Union Sulphur Co.
Virginia-Carolina Chemical Co.

Foreign Pyrites Section

A. D. Ledoux, Pyrites Co., Ltd., *chairman*
C. F. Burroughs, F. S. Royster Guano Co.
W. H. Mills, Naylor & Co., Inc.
W. H. Nichols, General Chemical Co.

American Metal Co., Ltd.
Ladenburg, Thalmann & Co.
Naylor & Co., Inc.
Pennsylvania Salt Mfg. Co.
Pyrites Co., Ltd.
Stranahan Pyrites Co., Ltd.
Virginia Smelting Co.
Weedon Mining Co., Ltd.

Tanning Extracts Section

Robt. W. Griffith, Champion Fibre Co., *chairman*
Robt. Y. Grant, Kingsport Extract Corp.
Albert McVitty, Buena Vista Extract Co.
John E. Oberne, Southern Extract Co.

Brevard Tanning Co.
Buena Vista Extract Co.
Champion Fibre Co.
John H. Heald & Co.
Kingsport Extract Corp.
Kistler, Lesh & Co.
Southern Extract Co.

Unassigned

Louisville Soap Co.

Appendix XIII

PREWAR WORLD CONSUMPTION OF CHILEAN NITRATE AND AMMONIUM SULFATE

(From *British Nitrogen Products Comm. Final Rept.*, 1920.)

	Nitrate (metric tons)			Sulfate (metric tons)	
	1911	*1912*	*1913*	*1912*	*1913*
Austria-Hungary	5,281	7,114	7,445	13,000	16,000
Belgium	303,780	309,817	318,515	42,000	45,700
Denmark	3,438	4,825	10,748	70	300
Egypt	19,018	23,981	25,638	1,650	2,000
France	338,706	354,517	327,192	90,000	97,000
Germany	743,412	911,962	833,112	425,000	460,000
Holland	144,652	180,924	164,502	8,000	8,000
Italy	53,616	44,545	51,690	29,500	33,000
Japan	—	—	—	87,000	115,000
Java	—	—	—	57,000	68,000
Spain	8,977	13,554	13,150	45,000[a]	75,000[a]
Sweden	—	—	—	1,300	1,350
Switzerland	2,371	5,198	—	—	—
United Kingdom	132,931	137,415	128,561	91,444	98,557
United States	568,136	441,047	589,187	250,139	266,850[b]
Other countries	77,074	95,746	87,233	—	—
Total	2,401,392	2,530,645	2,556,973	1,141,103	1,286,757

---

[a] Also Portugal; [b] ⅓ imported.

Appendix XIV

CHILEAN NITRATE EXPORTED TO U. S.

(From *For. Com. & Navig. U. S.; Min. Ind. 1923;* Curtis, *Fixed Nitrogen.*)

Year	Official Chilean Figures			Official U. S. Figures	
	Metric tons	*% to U. S.*	*Export duty*	*Long tons*	*Value*
1912.....	426,184	17.6	$ 6,036,190	486,352	$16,554,104
1913.....	572,196	21.5	7,381,874	625,862	21,630,811
1914.....	553,333	28.7	7,067,534	541,715	15,228,671
1915.....	864,055	43.3	7,231,339	772,190	22,959,997
1916.....	1,300,174	43.9	13,428,752	1,218,423	38,131,962
1917.....	1,593,826	57.0	15,808,587	1.543,213	60,437,526
1918.....	1,962,553	62.2	20,135,961	1,845,074	90,437,526
1919.....	294,874	36.7	16,873,888	407,459	19,558,963
1920.....	1,279,012	46.6	11,365,224	1,321,892	63,121,035
1921.....	131,174	10.9	10,572,263	369,173	17,982,977
1922.....	279,169	22.3	3,799,986	542,464	26,152,723

Appendix XV

U. S. LANDED POOL PRICES FOR SODIUM NITRATE *

1918	*Tentative*		*Final*	
	Refined/cwt. net	Ordinary/cwt. net	Refined/cwt. net	Ordinary/cwt. net
Jan.......	—	—	$4.68582	—
Feb......	—	--	4.3494512	$4.2900512
Mar......	—	—	4.0564571	3.9970571
Apr.......	—	—	4.0569056	3.9727156
May.....	$4.10	$4.05	4.00846	3.93913
June.....	4.10	4.05	4.040585	3.936585
July.....	4.20	4.10	4.03641	3.91755
Aug......	4.45	4.325	4.138794	4.019934
Sept......	4.50	4.325	4.169396	4.050536
Oct.......	4.525	4.40	—	—
Nov......	4.525	4.40	—	—
Dec.......	4.55	4.425	—	—

---

* C. H. MacDowell, to author, Nov. 4, 1942.

Appendix XVI

U. S. IMPORTS OF CALCIUM CYANAMIDE

(From *O.P.D. Reptr. Ann. Rept. 1930.*)

Fiscal Year	Long Tons	Value
1913	14,656	$ 777,774
1914	29,536	1,590,004
1915	20,564	919,574
1916	38,023	1,633,366
1917	44,146	1,951,104
1918	43,070	2,297,475
1919	46,149	2,705,475
1920	84,678	5,534,716
1921	34,702	2,443,450
1922	21,643	1,111,375

Appendix XVII

WORLD PRODUCTION OF NITROGEN (net tons N)

(From Nitrate Div., *Report on Fixation . . . of Nitrogen.*)

Source	*1913*	*1914*	*1915*	*1916*
Chilean nitrate	455,906	413,127	294,534	488,974
By-product ammonia	305,099	271,823	309,304	345,698
Cyanamide process	35,838	44,035	168,338	196,108
Haber process	6,798	13,596	33,990	67,980
Arc & other processes	19,800	23,000	26,000	29,000
Total fixed atmospheric N	62,436	80,631	228,326	293,088
Total N	823,441	765,581	832,164	1,127,760
	1917	*1918*	*1919*	*1920*
Chilean nitrate	503,474	479,622	276,945	422,685
By-product ammonia	368,991	370,000	309,000	391,400
Cyanamide process	232,304	231,829	—	130,000
Haber process	113,300	192,610	—	297,000
Arc & other processes	33,000	40,000	—	42,130
Total fixed atmospheric N	378,604	464,439	—	469,130
Total N	1,251,069	1,314,061	—	1,283,215

Appendix XVIII

U. S. NITROGEN STATISTICS (net tons N)

(From Ernst, *Fixation of Atmospheric Nitrogen.*)

	1913	*1916*	*1919*	*1920*	*1921*	*1922*
Domestic production						
By-product ammonia	39,330	59,383	86,960	102,401	73,501	97,474
Fixed atmospheric N	0	0	276	270	200	740
Total	39,330	59,383	87,236	102,671	73,701	98,487
Exports						
Chilean nitrate	0	9,337	2,384	3,456	5,765	2,265
By-product ammonia	0	104	12,100	20,300	23,563	33,831
Fixed atmospheric N	0	0	0	0	630	514
Total	0	9,441	14,484	23,756	29,958	36,610
Imports						
Chilean nitrate	109,351	212,867	71,200	230,480	66,249	94,581
By-product ammonia	13,481	2,991	542	459	1,075	1,123
Fixed atmospheric N	5,403	5,847	12,497	29,590	2,338	6,070
Total	128,235	221,705	84,239	260,529	69,662	101,774
Total consumption	167,565	271,647	156,991	339,444	113,405	163,651

Appendix XIX

COKE PRODUCTION IN U. S.

(From *Min. Res. 1924*, II, 598.)

Year	Beehive Coke *net tons*	By-Product Coke *net tons*	% By-Product
1912	32,868,433	11,115,164	25.3
1913	33,584,830	12,714,700	27.5
1914	23,335,971	11,219,943	32.5
1915	27,508,255	14,072,895	33.8
1916	35,464,224	19,069,361	35.0
1917	33,167,548	22,439,280	40.0
1918	30,480,792	25,997,580	46.0
1919	19,042,936	25,137,621	56.9
1920	20,511,092	30,833,951	60.0
1921	5,538,042	19,749,580	78.1
1922	8,573,467	28,550,545	76.9

Appendix XX

BY-PRODUCT COKE-OVEN PLANTS FOR ORDNANCE DEPARTMENT WITH ESTIMATED TOLUENE AND AMMONIUM SULFATE PRODUCTION

(From *Graham Comm. Hearings*, 1919-21.)

Company & Location	Ovens	Carbonizing Capacity	Toluene	Ammonium Sulfate	Estimated Completion
	type	*net tons/yr.*	*gal./yr.*	*net tons/yr.*	
[a] Jones & Laughlin Steel Corp. Pittsburgh	300 Koppers	1,915,200	957,600	23,940	Apr. 1919
[a] Rainey-Wood Coke Co. Swedeland, Pa.	110 Koppers	702,240	301,120	8,778	Nov. 1919
[b] Citizens Gas Co. Indianapolis	40 Wilputte	291,200	116,480 [c]	910 [d]	Mar. 1919
[a] Tennessee Coal, Iron & R.R. Co. Fairfield, Ala.	154 Koppers	1,010,625	336,875	10,611	Sept. 1919
[a] Carnegie Steel Co. Clairton, Pa.	128 Koppers	840,000	420,000	10,500	Sept. 1919
[b] Indiana Coke & Gas Co. Terre Haute	30 Koppers	197,000	60,000 [c]	542 [d]	Apr. 1919
[a] Pittsburgh Crucible Steel Co. Midland, Pa.	100 Koppers	637,000	318,000	7,960	Jan. 1920
[a] Sloss-Sheffield Steel Co. Birmingham	120 Semet-Solvay	770,000	231,000	8,085	Mar. 1920
[b] Seaboard By-Product Coke Corp. Jersey City	55 Koppers	360,930	144,375 [c]	4,151	Mar. 1919
[a] International Harvester Co. Chicago	88 Wilputte	633,600	316,800	7,286	Nov. 1919
[b] Domestic Coke Corp. Cleveland	60 Semet-Solvay	385,000	154,000	4,427	Feb. 1920
[a] Donner Union Coke Corp. Buffalo	150 Koppers	957,600	431,000	11,970	Mar. 1920
[b] Birmingham Coke & By-Products Co. Birmingham	50 Koppers	312,000	124,800	3,432	Oct. 1919
[b] Domestic Coke Corp. Fairmont, W. Va.	60 Koppers	383,200	191,600	4,790	Nov. 1919

---

[a] Replace beehive ovens; [b] Additional coking capacity; [c] Ordnance required to take production toluene and ammonia from existing ovens also; [d] Production of ammonia.

Appendix XXI

U. S. PRODUCTION OF AMMONIA AND AMMONIUM SULFATE

(From *Census of Dyes* & *Census of Mfrs.*)

Coke-Oven

Year	Anhydrous Ammonia [a]		Ammonium sulfate	
	pounds [b]	*value* [c]	*pounds* [b]	*value* [c]
1912	26,672,474	$2,387,562	95,275,545	$ 3,649,144
1913	28,663,936	2,135,656	173,342,349	5,324,444
1914	25,370,509	2,300,137	170,763,906	4,696,590
1915	30,002,196	2,978,044	199,900,487	5,648,958
1916	47,739,602	5,053,724	271,832,816	8,496,278
1917	47,784,345	4,823,446	352,722,848	11,973,468
1918	65,230,159	7,827,619	436,388,134	19,637,466
1919	50,535,639	5,692,950	544,231,985	21,075,718
1920	65,777,259	8,585,173	675,816,486	27,110,260
1921	32,090,560	3,525,551	528,638,763	13,100,703
1922	50,730,428	4,571,576	695,543,349	17,818,236

Other Sources

Year	Aqueous Ammonia		Anhydrous Ammonia		Ammonium Sulfate	
	pounds	*value* [c]	*pounds* [b]	*value* [c]	*pounds* [d]	*value* [c]
1914	35,544,246[d]	$1,412,236	29,361,355	$3,140,848	14,949,409	$ 422,628
1919	45,467,000[b]	2,241,321	27,957,000	7,224,473	65,846,000	3,190,894
1921	77,036,278[b]	2,795,760	29,361,355	6,198,671	14,949,409	331,930

---

[a] Mostly ammonia liquor sold on basis of lb. NH_3 content; [b] Total production; [c] Value of sales; [d] Production for sale.

Appendix XXII

U. S. PRODUCTION OF COAL-TAR CRUDES

(From *Census of Dyes.*)

Year	Coke-Ovens		Total, All Sources	
	gallons	*value*	*gallons*	*value*
		Benzene		
1915........	2,516,483	$ 1,428,323	—	—
1916........	21,079,500	13,159,374	—	—
1917........	36,804,228	16,576,865	40,441,922	$18,113,360[a]
1918........	44,804,900	12,341,779	52,240,758	14,617,743
1919........	44,060,970[b]	7,776,669[b]	—	—
	17,006,532[c]	3,783,552[c]	62,893,875[a]	12,120,768[a]
1920........	8,747,572[b]	401,296[b]	—	—
	16,977,556[c]	4,096,527[c]	26,600,689[a]	4,785,409[a]
1921........	1,494,329[b]	343,463[b]	—	—
	4,912,131[c]	1,268,258[c]	8,578,091[a]	2,074,926[a]
1922........	2,666,177[b]	698,437[b]	—	—
	10,419,504[c]	2,763,944[c]	18,794,102[a]	4,993,515[a]
		Toluene		
1915........	623,506	$ 1,529,803	—	—
1916........	3,939,636	11,238,268	—	—
1917........	7,395,174	10,140,013	10,219,830	$14,256,208
1918........	8,861,948	12,709,460	14,103,237[d]	20,891,945[d]
1919........	1,160,136[c]	355,990[c]	1,884,784[a,d]	596,511[a,d]
1920........	287,142[b]	—	—	—
	2,710,649[c]	2,470,364[c]	—	—
1921........	26,529[b]	4,410[b]	—	—
	942,982[c]	228,968[c]	—	—
1922........	38,159[b]	652[b]	—	—
	1,955,119[c]	556,363[c]	—	—
		Naphthalene		
1915........	196,151	$ 46,233	—	—
1916........	8,820,405	289,688	—	—
1917........	17,276,044	569,449	—	—
1918........	10,614,799[b]	293,414[b]	—	—
	5,472,699[c]	361,718[c]	56,924,619[d]	$1,945,951
1919........	3,549,998[b]	82,224[b]	—	—
	3,763,271[c]	109,120[c]	20,114,243[d]	542,565[d]
1920........	11,246,807[b]	307,999[b]	—	—
	2,921,282[c]	179,975[c]	42,602,466[a,d]	1,342,826
1921........	2,827,756[b]	40,659[b]	—	—
	115,229[c]	18,676[c]	19,432,987[d]	462,502[d]
1922........	6,107,742[b]	52,103[b]	—	—
	1,810,972[c]	79,149[c]	25,411,328[d]	536,209[d]

---

[a] Gas-plant figures incomplete; [b] Crude; [c] Refined; [d] Revised figures.

Appendix XXIII

U. S. PHENOL STATISTICS

(From *O.P.D. Reptr. Ann. Rept. 1930* & *Census of Dyes.*)

Year	Imports[a]		Exports[b]		Production	
	pounds	*value*	*pounds*	*value*	*pounds*	*value*
1913	8,345,631	$688,771	—	—	—	—
1914	8,393,216	531,535	—	—	—	—
1915	3,106,445	179,685	—	—	—	—
1916	2,246,256	154,841	—	—	—	—
1917	772,667	56,878	—	—	64,146,499	$23,715,805
1918	560,276	62,325	8,688,554	$4,236,288	106,794,277	37,270,284 [c]
1919	95,861	31,963	5,810,314	2,173,171	1,543,659	155,624
1920	30	14	2,223,205	420,101	(d)	(d)
1921	1,260	372	659,890	86,297	292,645	41,617
1922	—	361	111,479	19,008	1,266,552	268,311

---

[a] Fiscal yr., stated separately after 1923; [b] Fiscal yr., not stated after 1924; [c] Almost entirely synthetic; [d] Two producers, no statistics.

Appendix XXIV

TOTAL POTASH IMPORTS INTO U. S.*

(From Turrentine, *Potash*, p. 6.)

Year	Short Tons, K_2O	Value
1913	255,101	$13,200,413
1914	193,878	10,700,308
1915	42,519	3,257,114
1916	1,726	453,091
1917	504	189,159
1918	261	117,438
1919	28,484	4,163,739
1920	197,795	33,885,627
1921	64,036	7,743,364
1922	186,164	10,951,197

---

* See Appendix III for imports of individual potash salts

Appendix XXV

POTASH PRICES (per unit K_2O) *

(From Turrentine, *Potash*, p. 36.)

Year: Month	Muriate	Sulfate	Manure Salts	Kainite
1913	$0.76	$0.96	$0.68	$0.68
1914: Jan.-July	0.77	0.98	0.68	0.67
Aug.-Dec.	0.78	0.98	0.68	0.67
1915: Jan.	No quot.	No quot.	No quot.	No quot.
Feb.	No quot.	No quot.	No quot.	No quot.
Mar.	1.18	1.25	1.35	No quot.
Apr.	3.00	2.88	1.45	No quot.
May	2.95	2.88	1.60	No quot.
June	4.40	4.06	2.50	No quot.
July	4.82	4.23	2.75	3.63
Aug.	4.90	4.23	3.00	3.63
Sept.	4.90	4.23	3.00	3.63
Oct.	4.90	4.23	3.00	3.63
Nov.	8.26	7.81	3.00	3.63
Dec.	9.87	9.05	3.00	3.63
1916: Jan.	9.27	8.12	3.00	3.63
Feb.	9.00	6.94	2.75	3.63
Mar.	8.44	6.94	2.75	3.63
Apr.	8.06	6.94	2.75	3.63
May	7.34	6.94	2.75	3.63
June	6.33	5.39	2.75	3.63
July	5.98	5.93	2.75	3.63
Aug.	6.33	5.93	2.75	3.63
Sept.	7.42	5.93	2.75	3.63
Oct.	8.56	5.93	2.75	3.63
Nov.	8.56	5.93	2.75	3.63
Dec.	8.56	5.93	2.75	3.63
1917: Jan.	8.01	5.93	2.75	3.63
Feb.	8.58	5.93	2.75	3.63
Mar.	8.66	5.93	2.75	3.63
Apr.	7.72	5.93	2.75	3.63
May	8.51	5.93	2.75	3.63
June	8.06	5.93	2.75	3.63
July	7.60	5.93	2.75	3.63
Aug.	7.72	5.93	2.75	3.63
Sept.	7.17	6.66	Nom.	Nom.
Oct.	6.75	6.17	Nom.	Nom.
Nov.	6.83	7.58	Nom.	Nom.
Dec.	6.93	7.45	Nom.	Nom.
1918: Jan.	6.90	7.30	Nom.	Nom.
Feb.	6.88	7.30	Nom.	Nom.
Mar.	6.88	7.30	Nom.	Nom.
Apr.	6.78	7.97	Nom.	Nom.
May	6.78	7.97	Nom.	Nom.
June	6.13	7.97	Nom.	Nom.
July	5.64	7.01	Nom.	Nom.
Aug.	5.64	7.01	Nom.	Nom.
Sept.	5.64	7.01	Nom.	Nom.
Oct.	5.64	7.01	Nom.	Nom.

---

* Prices of other potash salts in Appendix II.

Year: Month	Muriate	Sulfate	Manure Salts	Kainite
1918: Nov.	$5.64	$7.01	Nom.	Nom.
Dec.	5.64	7.01	Nom.	Nom.
1919: Jan.	5.54	5.93	Nom.	Nom.
Feb.	5.54	5.93	Nom.	Nom.
Mar.	5.21	5.14	Nom.	Nom.
Apr.	Nom.	Nom.	Nom.	Nom.
May	Nom.	Nom.	Nom.	Nom.
June	3.31	Nom.	Nom.	Nom.
July	2.37	Nom.	Nom.	Nom.
Aug.	2.37	Nom.	Nom.	Nom.
Sept.	2.17	Nom.	Nom.	Nom.
Oct.	2.47	Nom.	Nom.	Nom.
Nov.	2.47	Nom.	Nom.	Nom.
Dec.	2.81	Nom.	Nom.	Nom.
1920: Jan.	2.88	Nom.	No quot.	No quot.
Feb.	2.93	4.00	No quot.	No quot.
Mar.	2.67	4.00	No quot.	No quot.
Apr.	2.53	4.00	No quot.	No quot.
May	2.49	3.75	No quot.	No quot.
June	2.40	3.50	No quot.	No quot.
July	2.40	3.50	No quot.	No quot.
Aug.	2.40	3.75	No quot.	No quot.
Sept.	2.33	2.98	No quot.	No quot.
Oct.	2.19	2.85	No quot.	No quot.
Nov.	2.17	2.85	No quot.	No quot.
Dec.	2.13	2.85	No quot.	No quot.
1921: Jan.	1.66	2.41	No quot.	No quot.
Feb.	1.50	2.15	No quot.	No quot.
Mar.	1.39	2.08	$1.11	$1.11
Apr.	1.11	1.78	1.49	0.97
May	1.02	1.50	0.86	0.85
June	0.99	1.38	0.75	0.78
July	0.93	1.35	0.78	0.78
Aug.	0.88	1.28	0.75	0.75
Sept.	0.85	1.23	0.73	0.73
Oct.	0.80	1.09	0.62	0.67
Nov.	0.74	0.94	0.55	0.60
Dec.	0.73	0.94	0.55	0.60
1922: Jan.	0.73	0.95	0.55	0.60
Feb.	0.71	0.95	0.55	0.60
Mar.	0.70	0.90	0.55	0.60
Apr.	0.70	0.91	0.55	0.60
May	0.65	0.85	0.52	0.57
June	0.60	0.80	0.48	0.54
July	0.61	0.80	0.49	0.60
Aug.	0.70	0.80	0.49	0.60
Sept.	0.68	0.80	0.49	0.61
Oct.	0.68	0.80	0.49	0.61
Nov.	0.71	0.94	0.53	0.58
Dec.	0.71	0.94	0.53	0.58

Appendix XXVI

POTASH FROM ALUNITE

by C. H. MacDowell *

In 1909, while in Berlin in connection with the German potash controversy, a German merchant named Manns, doing business in London, brought to my attention a deposit of alunite located near Almería in southern Spain. Manns introduced me to Dr. Scholler, managing director of what was known in English as the "Princes' Trust," owned by the Kaiser and his cronies. They wanted to sell us a group of potash mines. Manns submitted a preliminary report on the Spanish property. This suggested that if the ore was calcined at a high temperature, the alumina became insoluble and the potash in the form of sulfate could be leached out and recovered. The manager of Armour's English branch inspected the property, but his report was not favorable. The deposit, evidently of thermal springs origin, was shallow and small, and a sample of the ore proved to be aluminite rather than alunite; high in silica content and low in potash. I sent this sample to Chicago with instructions to give it to Chappell, and to have some preliminary research made on high-temperature calcination. This investigation showed that the alumina did become insoluble when the SO_3 was driven off, and that the potash could be recovered.

November 1910, when a committee called on President Taft, recommending that he ask the Congress for an appropriation enabling the Geological Survey to look for American potash deposits, the President asked me to discuss the subject with Dr. George Otis Smith, head of the Survey. During this interview I suggested alunite as a source material. He had received a report that morning from the Assay Office at Salt Lake City, announcing the discovery of what appeared to be an important deposit of alunite, near Marysvale, Utah. The reporter was named Custer, but the ore had been sent in by an old-time prospector, Tom Gillan, and identified as alunite. Custer immediately grubstaked Gillan, had him do some development work and stake out claims in Custer's name. On leaving Dr. Smith's office I returned to the Willard Hotel when Chappell called me from New York and informed me rather excitedly that on a visit to the Kalbfleisch office that morning he was shown a bag containing what was claimed to be high-grade alunite sent by a man named Custer from Salt Lake City. The ore looked good to him. I told Chappell of my talk with Dr. Smith and of his confirmation of the discovery.

Chappell went to Salt Lake City, got in touch with Custer, visited the property with Custer and Gillan, took a year's option. He found a mountainside covered with alunite float coming from a shattering of a projecting ledge; a short tunnel extending into the ledge; a surface outcropping continuing up the mountain 3,800 feet and at top some 800 feet higher than the tunnel. We agreed that Chappell would assume two thirds of the cost of the development and I would take one third. We decided to send out a young geologist, Lane, recently graduated from Chicago, and Hagerdon, a young mechanical engineer, University of Illinois, to make a thorough study of the territory from a geological standpoint, and also to supervise development work. Before leaving Marysvale, Chappell met Hoyt Gale of the Survey at the hotel. He was on his way to the property but it snowed hard that night and for several days and Gale was unable to visit the property until 1911. Our investigations were favorable and we purchased the claims, paying $25,000 for them. In 1912 the Geological Survey published Bulletin 511, "Alunite," by B. S. Butler and H. S. Gale.

The property contained a large deposit of unusually high-grade ore found in a vertical fissure vein with offshoots. The ore analyzed approximately 95% of theoretical on an average outcrop sampling. The average width of the vein when developed was 17 feet in the 1,800 feet opened up by the upper tunnel. The depth of the deposit was never determined. The end of the long tunnel was some 400 feet below the surface. There was no evidence of pinching out at depth. The lower tunnel entrance was at an elevation of 10,200 feet, 800 feet below the highest outcrop.

The Mineral Products Co. was organized to take over the property and conduct development work and research. Some stock was issued to Charles J. Faulkner, Jr., an Armour attorney, and now long general counsel for Armour & Co.; to Carl F. Hagerdon, a chemical engineer, vice-president of Armour Fertilizer Works in charge of manufacture; and to Richter, a Chappell colleague, as compensation for such services as they might extend.

---

* Memo to author, Oct. 16, 1943.

In a small laboratory in New York, Chappell directed research on the fundamental problems involved. The old European art was reviewed and their manufacturing methods confirmed. The ore values were contained in the potash and alumina content, with a possibility of utilizing the SO_3 in the aluminum sulfate. There was approximately 11% of uncombined alumina in the ore. The impurities were silica, iron, mostly as a secondary deposit, sodium sulfate, and .05% of phosphoric acid. Much of the silica was fissure filling from the country rock. The problem was to recover the potash and to obtain an alumina of commercial purity and soluble in reagents; if a pure alumina suitable for metal making or for an iron-free sulfate of alumina, so much the better. The dissociation temperature was found to be 750° C. At this temperature the alumina became water-insoluble and yet soluble in reagents. If the temperature was not reached soluble alums remained. If the temperature went much above 750° the alumina became insoluble in acids or alkalies, and at still higher temperature, the alumina became highly refractory and similar in character to white alundum, quite resistant to hydrofluoric acid. The temperature used in Italy and Germany was 500° C. At this temperature the water of crystallization was driven off, and the uncombined alumina could be converted into aluminum sulfate with sulfuric acid. In France, using another method, a temperature of 1,000° C. was said to be used. We found that much of the ore could be put into solution without calcining at room temperature and at atmospheric pressure. Potash alum was manufactured and from this a highly purified alumina was produced. Chappell removed the silica from the calcine with ammonium fluoride. Iron was the difficult problem; about sixty per cent was difficult to remove by any known method.

At that time we were in touch with Dr. Paul Hershman, a Viennese chemist living in Milwaukee, who was acquainted with Serpek, a French chemist, who had been researching the manufacture of aluminum nitride from bauxite, using producer gas as a source of nitrogen. From this nitride pure alumina and ammonia could be recovered by the Bayer process, with a claimed economy in the cost of soda used in the process. Hershman had been nitriding aluminum scrap and turnings, and thought we might use the product in fertilizer manufacture. We employed him to work on alunite, and he developed a number of interesting products, including potassium carbonate of unusual purity, which was produced during the First World War, for the manufacture of optical glass. He developed a carbon-alumina refractory which withstood unusually high temperatures—2,400° C. One of these refractories we used in the lining of an aluminum nitride furnace working at 1,700° C., with most satisfactory results. His chief research was the possibility of manufacturing commercially aluminum nitride from the alunite alumina. He found that in an atmosphere of nitrogen or even of producer gas he could progressively eliminate the SO_3, potash, and soda, and at 1,650° C. all of the silica was completely removed and the alumina made completely soluble. In doing this he produced aluminum nitride of varying concentrations, depending on the time and temperature used. He was unable completely to remove the iron. In this volatilization the potash could be recovered by one of several methods. Much of this work was carried on by Mark Shoelds, a chemical engineer, who later was to plan and operate a semicommercial aluminum nitriding plant.

In the spring of 1915 when potash values soared, we decided to construct a plant for the production of potash by simple high-temperature calcination. We asked some of our friends to join in the undertaking: U. S. Smelting, Refining & Mining Co., O. Armour, H. J. Baker & Bro., E. Klipstein of A. Klipstein & Co. The mining layout was in charge of Sidney Jennings, a vice-president of the Smelting Company. Westinghouse, Church, Kerr & Company constructed the plant and transportation system. An aerial conveyer a mile long extended from the mine to a canyon road leading to the plantsite. The ore was teamed downhill to the reduction plant. A road was constructed from the plant to a Sevier Valley road running into Marysvale, some five miles away, the terminal of a branch of the D. & R. G. extending from Salt Lake City. Good coal was available east of Salt Lake. Water rights were secured for the operation of the plant. The railroads named quite satisfactory rates in and out. Sulfate of potash was the preferred form in California, where we expected to market a fair share of the output.

The ore was to be calcined in a cement kiln, leached, filtered, and evaporated. A kiln 100 feet long had been ordered, but we sent two carloads of ore to the Illinois Steel Co. at South Chicago and reached the conclusion that a much longer kiln would be desirable. We were, however, unable to add more than ten feet to the length of the kiln, much to our regret. By late October the plant was in shape for a trial run. The mine in the meantime was opened up, and a tunnel which finally reached a length of 1,800 feet was driven into the ledge.

We planned to install producer gas equipment, but were unable to secure such equipment promptly, and resorted to pulverized coal. This introduced silica, iron, lime, and other impurities into the calcine, although much of the ash was carried out with the fume. Further, it made combustion control more difficult. Changes in barometric pressure quickly influenced combustion control. While the problem appeared simple, it took on some of the features of violin playing, and constant supervision was necessary. The kiln proved far too short for best results. The ore reached the hot zone too soon and ore shattering and dust losses occurred. We installed experimental dust collectors, changed the speed and pitch of the kiln, and gradually overcame most of the difficulties. If we undercalcined even a small portion of the ore, alums were produced and clogged the evaporator tubes. Overcalcination under reducing conditions produced potassium aluminate which caused evaporator difficulties. However we kept the plant going and produced a carload of 25 tons of potassium sulfate a day, analyzing 95% K_2SO_4. We recrystallized some of the product and produced a practically pure sulfate running 99.8% and better.

Appendix XXVII

U. S. Potash Production by Sources (short tons)

(From *Min. Res. 1920*, II, 98; *1921*, II, 53.)

	1915-16		*1917*		*1918*		*1919*	
	Crude	K_2O	Crude	K_2O	Crude	K_2O	Crude	K_2O
Mineral								
Natural brines	16,891	4,858	79,876	20,652	149,052	39,716	73,571	21,590
Alunite	3,036[a]	1,518	7,153	2,402	6,180	2,621	6,599	2,294
Dust, cement mills	5,435[a]	504	13,582	1,621	12,652	1,549	11,665	1,258
Dust, blast furnaces	185	11	2,133	185	2,954	205	1,101	127
Silicates	46	25	—	—	201	105	1,307	132
Organic								
Kelp	5,416[a]	1,574	11,306	3,572	14,029	4,804	368	132
Molasses distillery waste	7,775	1,799	8,589	2,846	11,792	3,467	8,791	2,892
Steffens waste water (beet-sugar refineries)	380	46	2,642	369	8,795	1,374	12,423	3,601
Wood ashes	825[b]	412	1,035	621	1,100	673	807	484
Miscellaneous industrial wastes	124	63	645	305	931	289	2	2
Total Produced	40,113	10,810	126,961	32,573	207,686	54,803	116,634	32,474
Total Plants	5[c] 70[d]		95		128		102	

---

[a] Production for 1915; [b] No figures for 1915; [c] 1915; [d] 1916.

Appendix XXVIII

POTASH CONTENT OF NATURAL U. S. BRINES

(From *Min. Res. 1916*, II, 83.)

Locality	*Material; number samples*	*% K_2O*
* Jesse Lake, Nebr.	Brine, 19% dissolved salts	5.96
* Searles Lake, Calif.	Saturated brine	2.48
* W. Nebr.	Brines; av. 13 lakes	1.91
Soda Lake, San Luis, Colo.	Saturated brine	1.62
* Salduro, Utah	Saturated brine	1.24
Death Valley, Calif.	Saturated brine; av. 14 samples	0.59
* Great Salt Lake, Utah	Brine, 20% dissolved salts	0.41
Little Alkali Lake, Oreg.	Brine, 11% dissolved salts	0.41
Saline Valley, Calif.	Saturated brine; av. 5 samples	0.35
* Owens Lake, Calif.	Brine, 11% dissolved salts	0.28
Utah Hot Springs, Utah	Water, 2⅓% dissolved salts	0.10
* Sea water (mean 77 analyses)	Water, 3½% dissolved salts	0.04

---

* Brines utilized for extraction of potash.

Appendix XXIX

U. S. PHOSPHATE ROCK AND SUPERPHOSPHATE STATISTICS

(From *Fertil. Rev.* 18, July-Aug. 1938.)

	Phosphate Rock (long tons)							*Superphosphate* (short tons)[d]
				Consumption[b, c]				
Year	Production[a]	Exports	Imports	Soil	Chemicals	Superphosphates	Total	Production[c]
1912	2,973,332	1,206,520	28,821	15,000	89,800	1,690,833	1,795,633	3,255,000
1913	3,111,221	1,366,508	17,121	40,000	88,000	1,633,834	1,761,834	3,146,000
1914	2,734,043	964,114	15,079	48,317	89,300	1,647,391	1,785,008	3,172,000
1915	1,835,667	253,421	5,359	50,468	95,300	1,441,837	1,587,605	2,776,000
1916	1,982,385	243,678	4,612	70,233	104,600	1,568,486	1,743,319	3,020,000
1917	2,584,287	166,358	92	75,861	145,000	2,197,160	2,418,021	4,230,000
1918	2,490,760	143,456	0	45,294	140,800	2,161,211	2,347,305	4,161,000
1919	2,271,983	378,731	0	79,189	113,600	1,700,463	1,893,252	3,274,000
1920	4,103,982	1,069,712	63	72,801	182,100	2,779,432	3,034,333	5,351,000
1921	2,064,025	733,312	3,535	13,503	93,400	1,227,345	1,334,248	2,363,000
1922	2,417,883	719,294	5,890	16,029	150,867	1,537,583	1,704,479	2,960,000

---

[a] Marketed; [b] U. S. & possessions; [c] Estimated; [d] See Appendix III for imports.

Appendix XXX

PHOSPHORIC ACID IN U. S.

(From *Census of Mfrs.* & *O.P.D. Reptr. Ann. Rept. 1930.*)

Year	Imports[a]		Production[b]		
	pounds	*value*	*pounds*	*value of sales*	*no. firms*
1913	504,383	$76,907	—	—	—
1914	528,827	63,222	12,420,191	$ 680,239	7
1915	265,193	39,120	—	—	—
1916	71,568	12,937	—	—	—
1917	13,666	4,225	—	—	—
1918	17,711	7,644	—	—	—
1919	6,431	4,186	22,109,302	1,711,148	9
1920	80,160	27,837	—	—	—
1921	253,700	68,189	8,942,695	898,744	11
1922	197,994	36,941	—	—	—

---

[a] Fiscal yr.; [b] Calendar yr.

Appendix XXXI

U. S. EXPORTS OF BAKING POWDER *

(From *O.P.D. Reptr. Ann. Rept. 1930.*)

Year	Pounds	Value
1912	2,615,138	$ 750,748
1913	2,846,575	844,826
1914	2,725,964	790,274
1915	3,376,780	881,879
1916	3,969,985	860,118
1917	4,836,844	1,028,352
1918	6,022,402	1,838,808
1919	4,257,487	1,257,805
1920	5,595,126	1,648,906
1921	3,491,666	1,229,400
1922	3,612,397	1,496,446

---

* Official figures for fiscal yr. Baking powder is primarily an American production, invented and commercially developed in the U. S. and more generally used here than in any other country.

Appendix XXXII

PYRITES IN U. S. (long tons)

(From *Min. Res. 1922*, II, 4.)

Year	Production	Imports[a]	Apparent Consumption[b]
1912	350,928	970,785	1,321,713
1913	341,338	850,592	1,191,930
1914	336,662	1,026,617	1,363,279
1915	394,124	964,637	1,358,761
1916	439,132	1,244,662	1,683,794
1917	482,662	967,340	1,450,002
1918	464,494	496,792	961,286
1919	420,647	388,973	809,620
1920	310,777	332,606	643,383
1921	157,118	216,229	373,347
1922	172,851	279,445	452,296

---

[a] Includes some private estimates; [b] Actual consumption varies considerably due to changes in consumer stockpiles. The S content of domestic pyrites was reported annually starting in 1918. Most of the years it has been close to 40%. The S content of imported pyrites has not been reported, but should average greater than 45%.

Appendix XXXIII

SULFUR IN U. S. (long tons)

(From *Min. Res. 1912*, II, 2.)

Year	Production	Total Shipments	Imports[a]	Exports[b]	Apparent Consumption[c]
1912	787,735	303,390	29,927	57,736	277,581
1913	491,080	319,333	22,605	89,221	252,717
1914	417,690	341,985	26,135	98,163	269,957
1915	520,582	293,803	26,367	37,312	282,858
1916	649,683	766,835	22,235	128,755	660,313
1917	1,134,412	1,120,378	973	152,736	968,615
1918	1,353,525	1,266,709	82	131,092	1,135,699
1919	1,190,575	678,257	101	224,712	453,646
1920	1,255,249	1,517,625	136	477,450	1,040,311
1921	1,879,150	954,344	50	285,762	668,632
1922	1,830,942	1,343,624	269	485,664	858,229

---

[a] All grades of S, including refined and ore, and some private estimates; [b] Crude S; [c] Total shipments less exports, plus imports. Actual consumption will differ due to variation in consumers' inventories and S in transit. See also Appendix III.

Appendix XXXIV

U. S. CONSUMPTION OF SULFUR FROM VARIOUS SOURCES (long tons)[a]

Year	Apparent Sulfur Consumption Brimstone[b]	U. S. Pyrites Production[c]	Pyrites Imports[d]	H_2SO_4 Copper and Zinc Smelters[e]	Total Sulfur
1912...	275,000	141,000	437,000	144,000	997,000
1913...	245,000	137,000	383,000	149,000	914,000
1914...	267,000	135,000	462,000	132,000	1,046,000
1915...	281,000	158,000	434,000	217,000	1,090,000
1916...	659,000	176,000	560,000	262,000	1,657,000
1917...	969,000	193,000	435,000	352,000	1,949,000
1918...	1,136,000	185,000	224,000	319,000	1,864,000
1919...	454,000	170,000	175,000	191,000	990,000
1920...	1,040,000	124,000	150,000	291,000	1,605,000
1921...	669,000	67,000	97,000	150,000	983,000
1922...	858,000	81,000	127,000	179,000	1,245,000

---

[a] No allowance for change in consumers' stocks, with S from H_2S and acid sludge excluded and pyrites and smelter gas in equiv. S; [b] From Bur. Mines, shipments plus imports, less exports; [c] From Bur. Mines, S content for 1912-17 calc. at 40%, other years as reported; [d] From Dept. Com., S content calc. at 45%; [e] 1912-20 from Census, 1921-22 estimated.

Appendix XXXV

ORGANIZATION MEETING OF THE COMMITTEE ON PRODUCTION—DISTRIBUTION —CONTROL OF SULFUR MATERIALS, N. Y., JUNE 7, 1918

Firms and Their Representatives Present

American Agricultural Chemical Co., W. M. Prescott, Horace Bowker, H. L. Dudley, C. M. Schultz
American Cyanamid Co., A. E. Bonn, C Davega Cohen
American Writing Paper Co., M. L. Cramer
American Zinc & Chemical Co., B. F. Phillipson, Otto Sussman
Anaconda Copper Mining Co., D. A. Welch
Anglo-Mexican Petroleum Co., Geo. W. Taylor
Arminius Chemical Co., Samuel Lee
Atlas Powder Co., A. L. Baptiste, R. T. Lytle, L. R. Hall, John E. Pool
Avery Chemical Co., Alan A. Claflin
H. J. Baker & Bro., Frank M. Smith
Barker Chemical Co., Ralph Barker
J. R. Baster Co., Herbert I. Thomas
Baugh Chemical Co., Oscar H. Elbert, R. M. Keating
Brown Co., W. M. Hoffses
Calco Chemical Co., R. Norris Shreve
Caraleigh Phosphate & Fertilizer Works, J. R. Chamberlain
Carthage Sulphite Pulp & Paper Co., D. W. Balmat
Central Chemical Co., W. P. O'Shaughnessy
Cleveland-Cliffs Iron Co., W. G. Mather, Chas. B. Hall
Contact Process Co., H. M. Rucker
Davison Chemical Co., C. Wilbur Miller, W. D. Huntington
De Grasse Paper Co., J. A. Outterson
Detroit Chemical Works, Edward S. Davis
Dow Chemical Co., James T. Pardee
E. I. du Pont de Nemours & Co., F. F. Chapman, Chas. L. Reese, P. S. Tilden, P. E. Garrett, A. W. Spicer
Eastern Mfg. Co., F. H. Purington
E. B. Eddy Co., Arthur E. O'Neill
Eustis Mining Co., A. H. Eustis
Farmers' Fertilizer Co., S. J. Martinet
Federal Chemical Co., Wood Crady, L. E. Stockard
Freeport Sulphur Co., S M. Swenson, A. W. Jenkins
Chas. F. Garrigues Co., Wm. H. Campbell

General Chemical Co., Wm. H. Nichols, Jr., A. W. Hawkes, W. H. Nichols
Grasselli Chemical Co., E. R. Grasselli, J. H. D. Rodier, E. W. Furst
Great Northern Paper Co., W. C. Powers
Griffith & Boyd Co., John T. Ensor
Hagerstown Spray Material Co., H. A. Bester, Jr., J. A. Long
Hammermill Paper Co., W. S. Epply
Hegeler Zinc Co., H. H. Roseman
Hercules Powder Co., L. J. Finnan, Jr.
Hooker Electrochemical Co., H. S. Farleigh
Louis D. Hunton
Illinois Zinc Co., Willard Fisher
International Agricultural Corp., S. B. Fleming
International Paper Co., Geo. E. Smith
Kalbfleisch Corp., Richard Sheldrick
Kershaw Mining Co., Bernard Cuniff
Krebs Pigment & Chemical Co., E. V. Granö
Lambert Chemical Co., M. H. Lambert
Lancaster Chemical Co., A. B. Hess
Lowell Fertilizer Co., Benjamin Moody
Marden, Orth & Hastings Co., H. D. Ruhm, D. H. Litter
Marietta Mining Co., C. C. Houston
Merrimac Chemical Co., Henry Howard, Lindsley Loring
Monsanto Chemical Works, J. F. Queeny
Munning-Loeb Co., C. G. Backus
Mutual Chemical Co., F. W. White, H. M. Kaufmann
Mutual Fertilizer Co., Chas. Ellis
National Sulphur Co., Arthur E. Beggs
Naugatuck Chemical Co., M. Adgate
Naylor & Co., A. H. Strong
New Jersey Zinc Co., J. H. Janeway, E. V. Peters
New York Pyrites Co., F. T. Rubidge
Niagara Sprayer Co., T. Dosch, H. S. Odell
Oxford Paper Co., D. B. Morris
Pennsylvania Salt Mfg. Co., Chas. M. Butterworth, Arthur E. Rice
Pennsylvania Trojan Powder Co., A. J. Striegel
Penobscot Chemical Fibre Co., G. E. Montague
Phosphate Mining Co., F. W. White
Pulp Mfrs'. Assoc., H. H. Bishop
Pyrites Co., Ltd., A. D. Ledoux
Reliance Fertilizer Co., Ralph Barker
Riverside Acid Works, Geo. J. Hesch
Robertson Fertilizer Co., W. H. Robertson
F. S. Royster Guano Co., C. F. Burroughs
St. Lawrence Pyrites Co., H. P. Nash
A. Schrader's Son, Inc., E. Eisenbraft
Smith Agricultural Chemical Co., Robt. B. Allen
Southern States Phosphate & Fertilizer Co., Porter Fleming
A. E. Staley Mfg. Co., Thos. L. Wolf
Stamford Rubber Supply Co., J. H. Mason
Standard Oil Co. (N. J.), F. H. Baldwin, C. A. Chumar
Standard Ultramarine Co., O. T. Frick
Stauffer Chemical Co., Arthur G. Howgill
Stranahan Pyrites Co., Ltd., C. B. Stranahan
Swift & Co., Frederick Rayfield
Taylor Chemical Co., C. E. Taylor, F. D. Berry
Tennessee Fertilizer Co., J. H. Carpenter
Thiogen Co. of America, John T. Overbury
I. P. Thomas & Son Co., A. Conrad Jones
Union Seed & Fertilizer Co., C. O. Phillips, L. F. Jackson
Union Sulphur Co., W. N. Wilkinson, S. S. Perry, H. Maynard
United Chemical & Organic Products Co., W. P. O'Shaughnessy
U. S. Glue Co., W. E. Hughes
U. S. Steel Corp. (incl. American Steel & Wire Co. and American Steel & Tin Plate Co.), John B. Carse
Victor Chemical Works, August Kochs
Virginia-Carolina Chemical Co., S. D. Crenshaw, C. G. Wilson
Weedon Mining Co., Ltd., Chas. H. Maxcy
West Virginia Pulp & Paper Co., Robt. H. Buckie
William Y. Westervelt, Ducktown Sulphur, Copper & Iron Co., Ltd.
Willcox, Ives & Co., C. L. Willcox
Willumsen Trading Co., C. Willumsen
Wilson & Toomer Fertilizer Co., Lorenzo A. Wilson
York Chemical Works, C. H. Dempwolf

Appendix XXXVI

U. S. IRON AND STEEL PRODUCTION

(From *Min. Res. 1918*, I, 571; *1923*, I, 317, 328; *1925*, I, 122.)

Year	Marketed Ferroalloys		Electrical Steel	Total Steel	Av. Price/Ton Pig Iron, Blast Furnaces
	gross tons	*value*	*gross tons*	*gross tons*	
1912.....	328,685	$ 12,223,776	18,309	31,251,303	$13.93
1913.....	296,207	13,015,362	30,180	31,300,874	15.08
1914.....	255,524	9,350,245	24,009	23,513,030	13.42
1915.....	388,644	17,450,385	69,412	32,151,036	13.21
1916.....	589,738 [a]	50,281,692	168,918	42,773,680	16.96
1917.....	634,021 [a]	83,731,724	304,543	45,060,607	27.29
1918.....	750,868 [a]	115,433,943	511,364	44,462,432	30.89
1919.....	419,648	53,730,964	384,452	34,671,232	25.75
1920.....	612,808	77,519,367	502,152	42,132,934	31.95
1921.....	248,627	21,697,785	169,499	19,783,797	24.28
1922.....	423,280	28,259,004	346,039	35,602,926	21.98

---

[a] Figures short of actual production, as output of certain electrically produced ferroalloys not available for publication.

Appendix XXXVII

RUSSIAN PLATINUM STORY

by Henry Howard

In 1917, shortly before the Kerensky Revolution in Russia, the Merrimac Chemical Company needed to buy platinum for our sulfuric acid contact process. Knowing most of the world's supply came from Russia, I found by investigation that the price in both Paris and London was between $50 and $60 an ounce, while in St. Petersburg, owing to an embargo by the Russian Government on the shipment of platinum, it was selling for about $35 per ounce. At that time we were manufacturing picric acid and synthetic phenol for the Russians for use in high explosives, and consequently I was able to get permission to export the necessary amount of platinum. I therefore purchased it from my friends, the Tentelevski Chemical Works of St. Petersburg, who were large dealers and refiners of platinum, and arranged with them to ship it in the form of platinized asbestos—the form in which we used it for the sulfuric acid process. I also instructed them to label the shipment "Asbestos" and make no mention of the fact that it contained platinum so that thieves would not be attracted. The payment was transferred by cable. I further arranged to have the shipment covered by war-risk insurance and for the American Express Company in St. Petersburg to ship it via Vladivostok over the Siberian railway and thence to Japan and the United States by the Pacific Mail Steamship Company. The platinized asbestos was packed in tins, hermetically sealed, each containing about two liters. These filled two large packing chests each about four feet cube. The shipment was made in due course and about two weeks after it left, the Kerensky Revolution occurred and all traces of the shipment vanished.

After making every possible effort to find it, we demanded payment from the insurance company. They refused on the ground that the loss had not been proved and that the material might turn up. We neglected to provide in the policy that if it did not turn up within a certain time this fact would be accepted as proof of loss of the material: an important point to remember in war-risk insurance. After about six months, we wrote off the whole transaction as a total loss and as we were so busy manufacturing war materials for our own Government, we forgot about the incident.

One day, more than a year after the shipment was made, we received a telegram from the War Department in Washington to the effect that two large packing cases labeled "Asbestos" with our name and address on them, had been found in a huge dump pile in the suburbs of Vladivostok. The telegram asked if the matter was of any interest to us. I immediately replied that it was of the utmost interest, and its receipt would assist in increasing our capacity for the production of war materials. It was therefore shipped on a U. S. warship from Vladivostok to Japan and thence by Pacific Mail from San Francisco and American Express to Boston, where it was opened and found to be intact—not even one gram of platinum missing, but best of all, the price of platinum in the United States had in the meantime advanced from $50 an ounce to $105 per ounce. The value at this price was between thirty and forty thousand dollars for the quantity involved.

Appendix XXXVIII

METALLIC MAGNESIUM PRODUCED IN U. S.

(From *Min. Ind. 1923*, 431; *Min. Res. 1915*, I, 737.)

Year[a]	Producers	Pounds	Value
1915..........	3	87,500	$440,000
1916..........	4	75,400	311,462
1917..........	5	115,813	233,626
1918..........	4	284,188	615,217
1919..........	3	127,465	247,302
1920..........	2	([b])	([b])
1921..........	1	48,000	86,000
1922..........	2	60,000[c]	89,000[c]

---

[a] No production before 1915; [b] Permission for publication not given; [c] Estimate.

Appendix XXXIX

U. S. PRODUCTION OF BORATE ORE AND REFINED BORAX[a]

(From *Census of Mfrs.* & *Min. Res.*)

Year	Borate Ore[b]		Refined Borax[c]	
	short tons	*value*	*short tons*	*value*
1913....	58,051	$1,491,530	—	—
1914....	62,400	1,464,400	26,501	$2,071,774
1915	67,003	1,677,099	26,794	2,293,631
1916....	103,525	2,409,459	27,969	3,353,432
1917....	108,875	3,609,632	28,309	3,805,711
1918....	88,794	2,179,830	26,673	3,909,565
1919....	66,146	1,380,000	29,635	4,622,286
1920....	120,320	2,173,000	35,281	5,674,012
1921....	50,000	1,320,000	18,499	2,745,192

---

[a] Exports 1920 fiscal yr., 5,472 tons, $905,607; 1921, 218 tons, $385,650; [b] All from Calif.; [c] Sales, 1914, 1919, 1921 figures from Census.

Appendix XL

U. S. BARYTES (short tons)

(From *Min. Ind. 1918*, 60; *1923*, 77.)

Year	Production	Consumption		
	Crude	*Ground barytes*	*Lithopone*	*Barium chemicals*
1912-14	45,174[a]	—	—	—
1915	108,547	53,903	44,503	10,216
1916	221,952	75,507	71,898	38,283
1917	206,888	60,132	86,065	49,842
1918	155,368	62,440	85,282	38,041
1919	209,330	64,922	103,688	32,976
1920	228,113	79,052	113,181	37,210
1921	66,369	28,296	61,359	10,952
1922	155,040	48,280	94,259	25,303

---

[a] Annual av.

Appendix XLI

U. S. TALC AND SOAPSTONE STATISTICS

(From *Min. Ind. 1920*, 653; *Min. Res. 1918*, I, 107A; *1922*, I, 87A, II, 82.)

Year	Production[a]		Imports[b]	
	short tons	*value*	*short tons*	*value*
1913	175,833	$1,908,097	13,770	$137,680
1914	172,833	1,865,087	15,734	177,321
1915	186,893	1,891,582	18,069	199,840
1916	213,561	2,253,803	18,882	230,875
1917	218,848	2,292,878	18,609	269,497
1918	208,507	2,681,019	14,169	260,576
1919	184,843	2,352,675	14,602	259,004
1920	210,635	3,035,449	22,680	450,720
1921	121,986	1,755,942	11,621	241,748
1922	198,684	2,859,897	18,444	277,378

---

[a] Marketed production of talc & soapstone; [b] Talc.

Appendix XLII

U. S. TALC PRODUCERS IN 1922 *

(From *Min. Res. 1922*, II, 82.)

American Mineral Co., Johnson, Vt.
American Soapstone Finish Co., Chester, Vt.
Blue Ridge Talc Co., Inc., Henry, Va.
Bull Run Talc & Soapstone Co., Clifton Sta., Va.
Carbola Chemical Co., Inc., L. I. City, N. Y.
Georgia Talc Co., Asheville, N. C.
Hartford Talc Co., Baltimore
Wallace W. Hite, Tecopa, Calif.
International Pulp Co., N. Y. C.
W. H. Loomis Talc Corp., Gouverneur, N. Y.
W. S. McLean, San Francisco
Magnesia Talc Co., Waterbury, Vt.
Maryland Mineral Co., Inc., Conowingo, Md.
G. W. Morton, Elsinore, Calif.
Herbert I. Oursler, Marriottsville, Md.
Pacific Coast Talc Co., Los Angeles
Rock Products Co., Easton, Pa.
Russi Soapstone Co., Folsom, Calif.
Sierra Talc Co., Los Angeles
Standard Mineral Co., Inc., N. Y. C.
Vermont Talc Co., Chester, Vt.
Virginia Alberene Corp., N. Y. C.
J. O. Wagner & Co., Easton, Pa.
C. K. Williams & Co., Easton, Pa.

---

* There were 37 producers in 1917.

Appendix XLIII

U. S. FULLER'S EARTH STATISTICS

(From *Min. Ind. 1922*, 249.)

Year	Production		Imports	
	short tons	*value*	*short tons*	*value*
1912	32,715	$ 305,522	19,109	$145,337
1913	38,594	369,750	18,628	145,588
1914	40,981	403,646	24,974	195,083
1915	47,901	489,219	19,441	152,493
1916	67,822	706,951	15,001	139,664
1917	72,567	772,087	16,994	176,417
1918	84,468	1,146,354	16,920	226,235
1919	106,145	1,998,829	13,873	189,711
1920	128,487	2,506,189	19,235	221,893
1921	105,609	1,973,848	9,744	119,415
1922	138,944	2,289,719	10,569	135,695

Appendix XLIV

U. S. FULLER'S EARTH PRODUCERS IN 1922 *

(From *Min. Ind. 1914*, 276.)

Adams & Bemis, Murfreesboro, Ark.
American Clay Co., Akran, Colo.
American Meat Packers' Assoc., Fairplay, Ark.
American Refiner's Earth Co., Klondyke, Ark.
Argyle Fuller's Earth Co., Argyle, S. D.
Arizona Earth Products Co., Benson, Ariz.
Atlantic Refining Co., Ellenton, Fla.
Commercial Pulverizing Co., Tex.
Eight Oil Co., Bakersfield, Calif.
J. E. & R. N. Farnsworth Co., Lancaster, Mass.
Florida Fuller's Earth Co., Ellenton, Fla.
Floridin Co., Quincy, Fla.
Fuller's Earth Co., Midway, Fla.
Fuller's Earth Co., Somerville, Tex.
Fuller's Earth Union, Ltd., Fairplay, Ark.
General Reduction Co., Pikes Peak, Ga.
Lester Clay Co., Attapulgus, Ga.
Manatee Fuller's Earth Corp., Ellenton, Fla.
National Fuller's Earth Co., Salters Depot, S. C.
John Olsen, Klondyke, Ark.
Palmetto Kaolin Co., S. C.
Somerville Development & Improvement Co., Somerville, Tex.
South Dakota Fuller's Earth Co., Rapid City, S. D.
Western Fuller's Earth Co., Vacaville, Calif.

---

* Companies italicized showed no production in 1914. In 1918, 99% domestic production came from Ala., Ark., Fla., Ga., and Tex.; Calif., Mass., and Nev. also reported. The list above gives mine locations.

Appendix XLV

U. S. NAVAL STORES

(From *Gamble's Naval Stores Year Book, 1926.*)

Year[a]	Production[b]		Exports[c]	
	Rosin (bbl., 500 lb.)	*Turpentine* (bbl., 50 U. S. gal.)	*Rosin* (bbl., 500 lb.)	*Turpentine* (bbl., 50 U. S. gal.)
1912-1913....	2,388,000	715,000	1,417,000	423,000
1913-1914....	2,250,000	675,000	1,471,000	378,000
1914-1915....	1,900,000	560,000	820,000	236,000
1915-1916....	1,767,000	530,000	869,000	192,000
1916-1917....	2,033,000	610,000	946,000	199,000
1917-1918....	1,700,000	520,000	734,000	107,000
1918-1919....	1,132,000	340,000	502,000	83,000
1919-1920....	1,330,000	400,000	730,000	214,000
1920-1921....	1,748,000	525,000	508,000	174,000
1921-1922....	1,665,000	500,000	675,000	209,000
1922-1923....	1,731,000	520,000	950,000	170,000

Percentage Production by States

State	*1914-1922 Range*
Alabama	10.08-12.26
Florida	34.04-45.83
Georgia	19.25-30.49
Louisiana, Mississippi, & Texas	19.58-31.50
North & South Carolina	0.46- 1.62

---

[a] Crop yr. ending Mar. 31; [b] Estimated, round figures. E. Van Romaine of Newport Industries gives somewhat higher estimates in *Chem. Ind.*, Sept. 1939; [c] Round figures.

Appendix XLVI

HOMER T. YARYAN: AN AUTOBIOGRAPHY

(Extract from *Hercules Mixer*, June 1928.)

I was born and lived in the town of Liberty, Ind., until I was 18 years of age, when my father moved to Richmond, Ind., which remained my home until the year 1879. I had in my youth the advantage of a private school. In this school there was a well-equipped laboratory, and I was particularly attracted by its mysteries. My father had a law office with a back room. In this room I established my own laboratory. I was only 12 years old and did not know of the dangers that lay in wait for me in these experiments. On this day I was trying to make some phosphorated hydrogen when a stick of phosphorus lying on the table took fire. The building was filled with smoke. The fire did little damage. I was thoroughly frightened and expected trouble, but to my surprise my father explained to the crowd how it happened, and ended by saying, "I guess I will have to make a chemist of that boy."

After our removal to Richmond, father got me admitted to the Chemical Works of W. J. M. Gordon & Bro., in Cincinnati. At that time there were but three manufacturers of chemicals in this country. They were Powers & Weightman, Rosengarten & Son, both of Philadelphia, and the Gordons. I stayed with Gordon & Bro. until the Civil War broke out, when I returned to Richmond.

In 1866 I went to Nashville. The boring for petroleum was then the rage and I found myself taken with the fever. My hunt for oil was rewarded by finding oil springs in Overton County, Tenn., and with the financial assistance of my brother and his partner, we began boring a well. At the depth of 64 feet we struck a vein that yielded 125 barrels a day. It was decided to build a refinery at Nashville, and in 3 months it was finished under the name of the Tennessee Oil Refining Co.

The first difficulty I ran up against was that the oil contained sulfur compounds which rendered it unfit for use on account of the odor. The only other oil of similar character was found in Canada. For 3 long months I worked on the problem. One day it came to me that in the manufacture of bisulfide of carbon we used soda plumbate to remove the free sulfur compounds that the raw distillate contained. I at once made some plumbate and treated the petroleum distillate. It instantly turned black and in a few minutes a precipitate of lead sulfide formed; the oil was free from bad odors. I published in the *Scientific American* of Sept. 1868 the process I had discovered, and the Canadian refineries began using it. It is still in use in many refineries and is known as the Canadian treatment, my connection with it long since having been forgotten.

In 1878 I built my first linseed oil mill for extracting oil from flaxseed by the solvent process at Richmond. In the years 1879-80 and '81 I licensed and erected mills in Chicago, Detroit, Toledo, Cleveland, Cincinnati, Philadelphia, St. Paul, San Francisco, and Indianapolis. Most of these mills operated until the hydraulic press was so improved that it left only 3% of oil in cake, as against 8% when I began building mills.

In 1883 I invented the Yaryan Multiple Effect Evaporator. For this invention I received the Franklin medal in 1885. In 1887 I formed a company to take over all foreign patents on this invention. My next invention was heating with hot water from a central station. I built 3 plants in Toledo between the years 1894 and 1896.

I now come to the most important part of my narrative; how I invented the process for extracting turpentine and rosin from stumps and fatwood. One day I read in a Toledo paper a local ad inviting people to invest in a new enterprise, which consisted of getting tar and turpentine from Michigan pine stumps. Out of curiosity I went to a room in the Chamber of Commerce Building where exhibits were shown of the products and the process explained. Of course, I knew it was a destructive distillation process, but what interested me were the samples of pine stumps they exhibited. I examined them and found they contained considerable quantities of rosin. I got samples, took them to an improvised laboratory and extracted the rosin easily with gasoline. Naturally my experience with linseed oil extraction led me to believe that it could be done in a commercial way by the use of this solvent. Little did I dream of what I should be up against when I determined to build an experimental plant in Toledo.

At the present time all big corporations have great research workers, each a specialist in his line of work, who solve all the difficult problems that may arise. But in my day it was a one man job, and to succeed, his mind had to be very versatile. Having decided, I went to a few of my friends and explained what I intended to do. I proposed to put up $25,000 of my own money and would allow them to subscribe $20,000 additional. They were to share with me pro rata any profits that might come of the venture. The money was subscribed and the Yaryan Process Co. was incorporated and began constructing the first plant for extracting rosin and turpentine from stumps.

I assumed, of course, there would be no trouble in obtaining stumps, but here I ran up against my first trouble. While the works were being built, I bought a stump-pulling outfit and employed a competent man and sent him to Michigan to get me a supply of stumps. After working 30 days and spending a lot of money, he returned with 2 carloads. He assured me that it was not practical or possible to pull stumps economically. I had known of fatwood in the South, and knew it was being steamed for turpentine. I at once got in touch with one of these plants, got samples of the wood and arranged to have 10 carloads shipped to me at once.

Having seen samples of chips that came from the "hogs," I knew they were not suitable for extracting the rosin. I found a wood chipper that wood pulp manufacturers used, which was guaranteed to chip 2 cords of wood an hour. When I began feeding the wood to the chipper it worked all right for 15 minutes, when it refused to take the "bite." It seems that wood containing rosin changed conditions. However, I had no time to remedy the trouble, so by sharpening the knives every 15 minutes, I managed to get 3 extractors filled and was ready to steam for turpentine. After this was done, I flooded with gasoline, drew off my solution of rosin, drained, and was ready for a steam out. When this was finished, the door was opened and we commenced taking out the chips. The chips were packed so tight that only a crowbar would move them.

Here was a new trouble, and I closed the door for the night. When I arrived the next day they had started to take out the chips and found a nice fire in the extractor. Here was another new trouble. I then proceeded to take solvents out of the solution with rosin. I had provided a still with steam coils and means for injecting live steam. This worked apparently all right, but when I drew out the rosin I found its color was "B" while laboratory experiments showed it to be "F." As there was in those days a difference of one dollar a barrel between "B" and "F," here was another trouble I had not dreamed of. I concluded to close down for a few days and think matters over.

First, the fire must have been caused by oxidation of the oil of pine left in the chips, hence the only remedy was to get chips out of the extractor without delay. The chips were not easily removed because the weight packed them solid at the bottom. The remedy, therefore, must be by removing the weight. These thoughts led me to introduce the breaker arms inside the extractor to sustain the weight. The next problem was easily solved, for I knew the color was caused by the long continued high heat. The "Yaryan" single effect would only heat the solution 2 minutes, so I ordered one.

Next came the chipper. I had a friend who was making extract of licorice for tobacco manufacturers. I knew he must shred his roots to obtain the extract, and so I visited his factory. There I saw the first shredder and immediately ordered one, also a hog, and when these were installed I had no further trouble with chips.

Other troubles that I had were as follows:

I sent some of the rosin to Sherwin-Williams Co. of Detroit to test and they condemned it at once. When they heated to the temperature of 500°, which they required, it "broke" at about 400°. This I found to be caused by oil of pine left in rosin. After much experimenting I succeeded in removing oil by running through another "Yaryan" under high pressure with an injection of steam under high vacuum.

Another trouble came from the "niger" the rosin contained. It clogged all our pipes so that every 2 weeks they had to be taken out and cleaned by heating. The paper manufacturers would not use the rosin because the "niger" clogged their screens. I finally remedied this by spraying the hot solution of rosin with cold water. My experimental plant was ready to show "Capital." I got J. K. Secor, a wealthy stock broker, interested, but he insisted that he must have an expert to confirm my statements. Mr. Joseph E. Lockwood was chosen. His report was favorable and Secor put up $120,000 to build the first plant in the South. Lockwood then came into the employ of the Yaryan Naval Stores Co. Finally the Gulfport plant was located.

A mistake of the Hercules Powder Co. caused a delay of more than a year in the use of dynamite for lifting stumps out of the ground. I had always believed that it could be done, and the matter came up for discussion after the Gulfport plant was finished. It was decided to write

Hercules and get their opinion. An answer came back promptly that it could be done and they would send dynamite and an expert to show us how it could be done. The expert came and began work which went on for 2 or 3 weeks. I looked at some of his work and must say that he made a fine grade of kindling wood. He finally reported that dynamite was not suitable for our needs.

After our Brunswick plant was built, we again wrote Hercules, relating past experiments to which they answered that evidently a mistake had been made in the grade of dynamite, and they were sure the lowest grade, which I think was called 20%, would do the work. We ordered a lot, and it certainly did the work.

The [Gulfport] plant operated for a year successfully, and it was decided to increase the capital and build one much larger at Brunswick, Ga.

Such is the history of an enterprise which I believe in the not far distant future will supply the world with rosin and turpentine, and I further believe that the Hercules Powder Co. will be the controlling factor when that time arrives, to which I say "Amen," for they certainly will have earned that enviable position by their pluck and foresight.

BOOK TITLES

Adamic, Louis. *Two-Way Passage.* N. Y., Harper, 1941.

Addicks, Lawrence. *Copper Refining.* N. Y., McGraw-Hill, 1921.

Allen, J. Fenwick. *Some Founders of the Chemical Industry.* London, Sherratt & Hughes, 1906.

American Armies and Battlefields in Europe. American Battle Monuments Comm., Wash., D. C., Govt. Prtg. Off., 1938.

Anderson, Benjamin Mc., Jr. *The Value of Money.* N. Y., Smith, 1936.

Angell, Sir Norman. *The Story of Money.* N. Y., Stokes, 1929.

Annin, Robert E. *Woodrow Wilson.* N. Y., Dodd, Mead, 1924.

Ashley, Percy W. L. *Modern Tariff History: Germany, United States, France.* 2d ed. London, Murray, 1910.

Auden, Harold A. *Sulphur and Sulphur Derivatives.* London, Pitman, 1921.

Austin, Leonard S. *The Metallurgy of Common Metals, Gold, Silver, Iron (and Steel), Copper, Lead, and Zinc.* 6th ed., rev. N. Y., Wiley, 1926.

Bain, H. Foster. *Ores and Industry in the Far East.* N. Y., Council For. Relations, 1927.

Barnett, Edward de B. *Anthracene and Anthraquinone.* N. Y., Van Nostrand, 1921.

Baruch, Bernard M. *American Industry in the War: A Report of the War Industries Board (March 1921).* N. Y., Prentice-Hall, 1941.

Bastable, Charles F. *The Commerce of Nations.* London, Methuen, 1892.

Bauer, John, and Nathaniel Gold. *The Electric Power Industry.* N. Y., Harper, 1939.

Beard, Charles A., and Mary R. Beard. *The Rise of American Civilization.* N. Y., Macmillan, 1930.

Bergman, M. L. *Manufacturing Processes.* N. Y., Wiley, 1942.

Beveridge, Albert J. *The State of the Nation.* Indianapolis, Bobbs-Merrill, 1924.

—— *What is Back of the War.* Indianapolis, Bobbs-Merrill, 1915.

Black, John D. *Introduction to Production Economics.* N. Y., Holt, 1926.

Bogart, Ernest L., and Charles E. Landon. *Modern Industry.* N. Y., Longmans, Green, 1927.

Bone, William A. *Coal and Its Scientific Uses.* N. Y., Longmans, Green, 1918.

Bowers, Claude G. *Beveridge and the Progressive Era.* N. Y., Houghton Mifflin, 1932.

Brady, Robert A. *The Rationalization Movement in German Industry.* Berkeley, Calif., U. Calif. Press, 1933.

Brown, Sevellon. *The Story of Ordnance in the World War.* Wash., D. C., Bryan Press, 1920.

Bücher, Karl. *Industrial Evolution.* Tr. from 3d German ed. by S. Morley Wickett. N. Y., Holt, 1901.

Bunbury, Hugh M., and Alexander Davidson. *Industrial Applications of Coal-Tar Products.* N. Y., Van Nostrand, 1925.

Cain, John C. *The Manufacture of Intermediate Products for Dyes.* N. Y., Macmillan, 1919.

——, and Jocelyn F. Thorpe. *The Synthetic Dyestuffs and the Intermediate Products from Which They Are Derived.* 7th ed., rev. by Thorpe and Reginald P. Linstead. London, Griffin, 1933.

Carver, Thomas N. *The Present Economic Revolution in the United States.* Boston, Little, Brown, 1925.

Cassel, Gustav. *The World's Monetary Problems.* London, Constable, 1921.

Channing, Edward. *The Jeffersonian System, 1801-1811.* N. Y., Harper, 1906.

Chase, Stuart. *Men and Machines.* N. Y., Macmillan, 1929.

—— *The Tragedy of Waste.* N. Y., Macmillan, 1925.

Chemical Progress in the South. Comp. & ed. by Nat. Res. Council. N. Y., Chem. Found., 1930.

Christopher, John E. *Modern Coking Practice.* (Including the Analyses of Materials and Products, by T. H. Byrom.) 3d ed. N. Y., Van Nostrand, 1921, 2 v.

Churchill, Winston L. S. *The World Crisis.* N. Y., Scribner's, 1931.

Clark, Champ. *My Quarter Century in American Politics.* N. Y., Harper, 1920, 2 v.

Clark, John M., and others, ed. *Readings in the Economics of War.* Chicago, U. Chicago Press, 1918.

Clark, Victor S. *History of Manufactures in the United States.* N. Y., McGraw-Hill, 1929, 3 v.

Clarkson, Grosvenor B. *Industrial America in the World War.* Boston, Houghton Mifflin, 1923.

Corson, Michael G. *Aluminum: The Metal and Its Alloys.* N. Y., Van Nostrand, 1926.

Cottrell, Allin. *The Manufacture of Nitric Acid and Nitrates.* N. Y., Van Nostrand, 1923.

Cowdrick, Edward S. *Industrial History of the United States.* N. Y., Ronald Press, 1923.

Crowell, Benedict. *America's Munitions, 1917-18.* Wash., D. C., Govt. Prtg. Off., 1919.

——, and Robert F. Wilson. *The Armies of Industry: Our Nation's Manufacture of Munitions for a World in Arms, 1917-1918.* New Haven, Yale U. Press, 1921, 2 v.

—— *The Giant Hand. Our Mobilization and Control of Industry and Natural Resources, 1917-1918.* New Haven, Yale U. Press, 1921.

Crozier, William. *Ordnance and the World War.* N. Y., Scribner's, 1920.

Culbertson, William S. *International Economic Policies.* N. Y., Appleton, 1925.

Curtis, Harry A. *Fixed Nitrogen.* N. Y., Chem. Catalog, 1932.

Daggett, Harriet S. *Mineral Rights in Louisiana.* Baton Rouge, La. State U. Press, 1939.
Davenport, Herbert J. *The Economics of Enterprise.* N. Y. Macmillan, 1913.
Dawson, William H. *The Evolution of Modern Germany.* London, Unwin, 1908.
Dewey, Davis R. *Financial History of the United States.* 10th ed. N. Y., Longmans, Green, 1928.
De Witt, Benjamin P. *The Progressive Movement.* N. Y., Macmillan, 1915.
Dunn, Arthur W. *From Harrison to Harding.* N. Y., Putnam's, 1922, 2 v.
Dunstan, Albert E., and others, ed. *The Petroleum Industry.* N. Y., Inst. Petr. Tech., 1922.
—— *The Science of Petroleum.* London, Oxford U. Press, 1938, 4 v.
Durgin, William A. *Electricity, Its History and Development.* Chicago, McClurg, 1912.
Dutton, William S. *Du Pont: One-Hundred and Forty Years.* N. Y., Scribner's, 1942.

Eckel, Edwin C. *Coal, Iron and War.* N. Y., Holt, 1920.
Edwards, Junius D., Francis C. Frary, and Zay Jeffries. *The Aluminum Industry.* N. Y., McGraw-Hill, 1930, 2 v.
Ernst, Frank A. *Fixation of Atmospheric Nitrogen.* N. Y., Van Nostrand, 1928.

Fairchild, David G. *Exploring for Plants.* N. Y., Macmillan, 1930.
—— *The World Was My Garden: Travels of a Plant Explorer.* N. Y., Scribner's, 1938.
Fairlie, Andrew M. *Sulphuric Acid Manufacture.* N. Y., Reinhold, 1936.
Farnham, Dwight T. *America vs. Europe in Industry.* N. Y., Ronald Press, 1921.
Fisher, Irving. *The Purchasing Power of Money.* N. Y., Macmillan, 1925.
Foster, William T., and Waddill Catchings. *Money.* Boston, Houghton Mifflin, 1923.
—— *Profits.* Boston, Houghton Mifflin, 1925.
Fraser, Herbert F. *Foreign Trade and World Politics.* N. Y., Knopf, 1926.
Fuller, Henry C. *The Story of Drugs.* N. Y., Century, 1922.

Gamble's Naval Stores Year Book. Savannah, Ga., 1926.
Gardner, Walter M., ed. *The British Coal-Tar Industry.* London, Williams & Norgate, 1915.
Garrett, Garett. *The American Omen.* N. Y., Dutton, 1928.
Garrett, Paul W. *Government Control Over Prices.* Wash., D. C., Govt. Prtg. Off., 1920.
Glass, Carter. *An Adventure in Constructive Finance.* Garden City, N. Y., Doubleday, Page, 1927.

Glover, John G., and William B. Cornell, ed. *The Development of American Industries.* Rev. ed. N. Y., Prentice-Hall, 1941.
Greer, Guy. *The Ruhr-Lorraine Industrial Problem.* N. Y., Macmillan, 1925.
Groggins, Philip H. *Aniline and Its Derivatives.* N. Y., Van Nostrand, 1924.

Hale, Harrison. *American Chemists.* 2d ed. N. Y., Van Nostrand, 1928.
Hale, William J. *Chemistry Triumphant.* Baltimore, Williams & Wilkins, 1932.
Haynes, Williams. *Chemical Economics.* N. Y., Van Nostrand, 1933.
—— *Chemical Pioneers.* N. Y., Van Nostrand, 1939.
—— *Dyes Made in America, 1915-1940.* N. Y., Calco Chemical Division, American Cyanamid Co., 1940.
—— *Men, Money and Molecules.* (Including Chronology of American Chemical Industry, by W. Haynes and L. W. Bass.) N. Y., Doubleday, 1936.
—— *The Stone That Burns: The Story of the American Sulphur Industry.* N. Y., Van Nostrand, 1942.
—— *This Chemical Age.* 2d ed. N. Y., Knopf, 1942.
Helfferich, Karl. *Money.* Tr. by Louis Infield. London, Benn, 1927, 2 v.
Hendrick, Burton J. *The Life and Letters of Walter H. Page,* Garden City, N. Y., Doubleday, Page, 1922-25, 3 v.
Hibben, Paxton. *The Peerless Leader: William Jennings Bryan.* N. Y., Farrar & Rinehart, 1929.
Hilditch, Thomas P. *Catalytic Processes in Applied Chemistry.* N. Y., Van Nostrand, 1929.
Holland, Maurice C., and Henry F. Pringle. *Industrial Explorers.* N. Y., Harper, 1928.
Houston, Henry. *The Fundamentals of Money.* London, King, 1935.
Hubbard, William H. *Cotton and the Cotton Market.* N. Y., Appleton, 1923.
Humphrey, Edward F. *An Economic History of the United States.* N. Y., Century, 1931.

Jeffrey, Edward C. *Coal and Civilization.* N. Y., Macmillan, 1925.
Jennings, Walter W. *A History of the Economic and Social Progress of the American People.* Cincinnati, South-Western Pub. Co., 1937.

Keir, R. Malcolm. *Manufacturing Industries in America.* N. Y., Ronald Press, 1920.
Kemmerer, Edwin W. *Modern Currency Problems.* N. Y., Macmillan, 1916.
—— *Money.* N. Y., Macmillan, 1935.
—— *The A B C of the Federal Reserve System.* 9th ed. Princeton, N. J., Princeton U. Press, 1932.
Kerwin, Jerome G. *Federal Water Power Legislation.* N. Y., Columbia U. Press, 1926.
Keynes, John M. *The Economic Consequences of the Peace.* N. Y., Harcourt, Brace, 1920.
King, Willford I. *Income in the United States.* Nat. Bur. Econ. Res., N. Y., Harcourt, Brace, 1921, 2 v.

Knox, Joseph. *The Fixation of Atmospheric Nitrogen.* N. Y., Van Nostrand, 1914.

Kohlsaat, Herman H. *From McKinley to Harding.* N. Y., Scribner's, 1923.

Kreps, Theodore J. *The Economics of the Sulfuric Acid Industry.* Stanford, Calif., Stanford U. Press, 1938.

Leland, Waldo G., and Newton D. Mereness. *Introduction to the American Official Sources for the Economic and Social History of the World War.* New Haven, Yale U. Press, 1926.

Liefmann, Robert. *Cartels, Concerns and Trusts.* N. Y., Dutton, 1932.

Lindquist, Everet F. *A First Course in Statistics.* Rev. ed. Boston, Houghton Mifflin, 1942.

MacDowell, Charles H. *The Problems of Muscle Shoals.* Chicago, 1925.

Marshall, Alfred. *Industry and Trade.* London, Macmillan, 1919.

Marshall, Arthur. *Explosives.* 2d ed. Phila., Blakiston, 1917-32, 3 v.

Martin, Robert F. *International Raw Commodity Price Control.* N. Y., Nat. Ind. Conference Bd., 1937.

Mathewson, Champion H., ed. *Modern Uses of Non-Ferrous Metals.* N. Y., Am. Inst. Min. Met. Engrs., 1935.

Matthews, Frank W. *Commercial Commodities.* London, Pitman, 1921.

Matthews, Joseph M. *The Textile Fibers.* 4th ed. N. Y., Wiley, 1924.

McVey, Frank L. *Modern Industrialism.* 2d ed. N. Y., Appleton, 1923.

Miall, Stephen. *A History of the British Chemical Industry.* London, Benn, 1931.

Mills, Frederick C. *The Behavior of Prices.* N. Y., Nat. Bur. Econ. Res., 1927.

Mitchell, Wesley C. *Business Cycles.* N. Y., Nat. Bur. Econ. Res., 1927.

Moore, Elwood S. *Coal.* 2d ed. N. Y., Wiley, 1940.

Moore, Raymond C., ed. *Geology of Salt Dome Oil Fields.* Houston, Tex., Am. Assoc. Petr. Geol., 1926.

Morgan, Sir Gilbert, and David D. Pratt. *British Chemical Industry: Its Rise and Development.* London, Arnold, 1938.

Morrow, Lester W. W. *Electric Power Stations.* N. Y., McGraw-Hill, 1927.

Navy Ordnance Activities: World War, 1917-18. Wash., D. C., Govt. Prtg. Off., 1920.

Noble, Henry G. S. *The New York Stock Exchange and the Crisis of 1914.* Garden City, N. Y., Country Life Press, 1915.

Noyes, Alexander D. *Forty Years of American Finance.* N. Y., Putnam's, 1909.

Noyes, Arthur A. *Qualitative Chemical Analysis of Inorganic Substances.* 10th ed., rev. & rewritten by Ernest H. Swift. N. Y., Macmillan, 1942.

Ogg, Frederic A. *Economic Development of Modern Europe.* N. Y., Macmillan, 1926.

Parsons, Floyd W. *Everybody's Business.* Garden City, N. Y., Doubleday, Page, 1923.
Peattie, Donald C. *Cargoes and Harvests.* N. Y., Appleton, 1926.
Pigou, Arthur C. *Industrial Fluctuations.* London, Macmillan, 1927.
Porter, Horace C. *Coal Carbonization.* N. Y., Chem. Catalog, 1924.
Pound, Arthur. *The Iron Man in Industry.* Boston, Houghton Mifflin, 1922.
Powers, Harry H. *The American Era.* N. Y., Macmillan, 1920.
Prentiss, Augustin M. *Chemicals in War.* N. Y., McGraw-Hill, 1937.

Read, William T. *Industrial Chemistry.* 2d ed. N. Y., Wiley, 1938.
Redfield, William C. *Dependent America.* Boston, Houghton Mifflin, 1926.
Richards, Joseph W. *Metallurgical Calculations.* Pt. 1-3, 2d ed. N. Y., McGraw, 1907-8, 3 v.
Rideal, Eric K., and Hugh S. Taylor. *Catalysis in Theory and Practice.* London, Macmillan, 1926.
Ripley, William Z. *Main Street and Wall Street.* Boston, Little, Brown, 1927.
Rogers' Industrial Chemistry. 4th ed. N. Y., Van Nostrand, 1925, 2 v.
—— 6th ed. by Clifford C. Furnas. N. Y., Van Nostrand, 1942, 2 v.
Roosevelt, Theodore. *Autobiography.* N. Y., Scribner's, 1920.
—— *Works.* Memorial ed. N. Y., Scribner's, 1925, 24 v.
Rorem, Clarence R., and H. D. Kerrigan. *Accounting Method.* 3d ed. N. Y., McGraw-Hill, 1942.
Rose, Sir T. Kirke. *The Metallurgy of Gold.* 6th ed. London, Griffin, 1915.
Rusby, Henry H. *Jungle Memories.* N. Y., McGraw-Hill, 1933.
Russell, Sir William H. *A Visit to Chili and the Nitrate Fields of Tarapaca.* London, Virtue, 1890.

Seligman, Edwin R. A. *The Economics of Farm Relief.* N. Y., Columbia U. Press, 1929.
Seymour, Charles. *The Intimate Papers of Colonel House Arranged as a Narrative.* Boston, Houghton Mifflin, 1926-28, 4 v.
Shannon, Fred A. *Economic History of the People of the United States.* N. Y., Macmillan, 1934.
Shipley, Maynard. *The War on Modern Science.* N. Y., Knopf, 1927.
Siegfried, André. *America Comes of Age.* Tr. from French, by H. H. and Doris Hemming. N. Y., Harcourt, Brace, 1927.
Slosson, Edwin E. *Creative Chemistry.* N. Y., Century, 1920.
Slosson, Preston W. *The Great Crusade and After, 1914-1928.* N. Y., Macmillan, 1930.
Smith, Ernest A. *The Platinum Metals.* N. Y., Pitman, 1925.
Smith, James G. *Economic Planning and the Tariff.* Princeton, N. J., Princeton U. Press, 1934.
Smittrells, Colin J. *Tungsten: A Treatise on Its Metallurgy, Properties, and Application.* 2d ed. N. Y., Van Nostrand, 1936.
Spurr, Josiah E., and Felix E. Wormser, ed. *The Marketing of Metals and Minerals.* N. Y., McGraw-Hill, 1925.

Stocking, George W. *The Potash Industry: A Study in State Control.* N. Y., Smith, 1931.
Sullivan, Thomas J. *Sulphuric Acid Handbook.* N. Y., McGraw-Hill, 1918.
Swain, Joseph W. *Beginning the Twentieth Century: A History of Europe from 1870 to the Present.* Rev. ed. N. Y., Norton, 1938.

Taussig, Frank W. *The Tariff History of the United States.* 8th ed. N. Y., Putnam's, 1931.
Taylor, Hugh S. *Industrial Hydrogen.* N. Y., Chem. Catalog, 1921.
Teeple, John E. *The Industrial Development of Searles Lake Brines, with Equilibrium Data.* N. Y., Chem. Catalog, 1929.
The Chemical Alliance, Inc. (Historical Review of Its Object, Organization, and Activities Compiled for History Bur., General Staff, U. S. War Dept.) N. Y., 1920.
The General Chemical Company after Twenty Years, 1899-1919. N. Y., 1919.
Thornton, William M., Jr. *Titanium, with Special Relation to Analysis of Titaniferous Substances.* N. Y., Chem. Catalog, 1927.
Toothaker, Charles R. *Commercial Raw Materials.* Rev. ed. Boston, Ginn, 1927.
Tripp, Guy E. *Super Power as an Aid to Progress.* N. Y., Putnam's, 1924.
Tumulty, Joseph P. *Woodrow Wilson as I Know Him.* Garden City, N. Y., Doubleday, Page, 1921.
Turrentine, John W. *Potash.* N. Y., Wiley, 1926.

Van Gelder, Arthur P., and Hugo Schlatter. *History of the Explosives Industry in America.* N. Y., Columbia U. Press, 1927.
Veblen, Thorstein. *Imperial Germany and the Industrial Revolution.* N. Y., Macmillan, 1915.
Villard, Oswald G. *Prophets True and False.* N. Y., Knopf, 1928.
Viner, Jacob. *Dumping: A Problem in International Trade.* Chicago, U. Chicago Press, 1923.
Voskuil, Walter H. *The Economics of Water Power Development.* Chicago, Shaw, 1928.

Waeser, Bruno. *The Atmospheric Nitrogen Industry.* Tr. by Ernest Fyelman. London, Churchill, 1926, 2 v.
Waggaman, William H., and Henry W. Easterwood. *Phosphoric Acid, Phosphates and Phosphatic Fertilizers.* N. Y., Chem. Catalog, 1927.
Walker, J. Bernard. *The Story of Steel.* N. Y., Harper, 1926.
Wallace, Benjamin B., and Lynn R. Edminster. *International Control of Raw Materials.* Wash., D. C., Brookings Inst., 1930.
Warburg, Paul M. *The Federal Reserve System.* N. Y., Macmillan, 1930, 2 v.
Warner, Charles A. *Texas Oil and Gas since 1543.* Houston, Tex., Gulf Pub. Co., 1939.
Warshow, Herman T., ed. *Representative Industries of the United States.* N. Y., Holt, 1928.
Wells, H. G. *The Future in America.* N. Y., Harper, 1906.

Wells, Louis R. *Industrial History of the United States.* N. Y., Macmillan, 1922.
Werner, M. R. *Bryan.* N. Y., Harcourt, Brace, 1929.
Wile, Frederic W., ed. *A Century of Industrial Progress.* N. Y., Doubleday, 1928.
Williams, William B. *History of Manufacture of Explosives for the World War, 1917-1918.* Chicago, U. Chicago Press, 1920.
—— *Munitions Manufacture in the Philadelphia Ordnance District.* Phila., Pomerantz, 1921.
Willis, Henry P. *The Federal Reserve System.* N. Y., Ronald Press, 1923.
Winkler, John K. *The Du Pont Dynasty.* N. Y., Reynal & Hitchcock, 1935.
—— *Tobacco Tycoon: The Story of James Buchanan Duke.* N. Y., Random, 1942.
World Conditions as to Mineral Raw Materials for the Fertilizer Industry. Phila., Nat. Fertil. Assoc., 1926.
Wyld, Wilfrid. *Raw Materials for the Manufacture of Sulphuric Acid and the Manufacture of Sulphur Dioxide.* (In G. Lunge, *The Manufacture of Acids and Alkalies*, vol. 1.) Rev. ed. N. Y., Van Nostrand, 1923.

Zanetti, J. Enrique. *The Significance of Nitrogen.* N. Y., Chem. Found., 1932.
Zon, Raphael, and William N. Sparhawk. *Forest Resources of the World.* N. Y., McGraw-Hill, 1923, 2 v.

ACKNOWLEDGMENTS

MANY MEN have helped me in the writing of these two volumes. This will be evident to every reader. There is certain assistance, however, that cannot be acknowledged in a footnote or a reference and these punctilious, but perfunctory evidences of an author's indebtedness in no way express my gratitude. And I am indeed grateful, for I am keenly aware how much the following pages owe to their generous collaboration.

A devoted band has read the entire manuscript: Marston T. Bogert, Gaston F. DuBois, Lammot du Pont, Hugh A. Galt, Henry Howard, Robert C. Jeffcott, Charles H. MacDowell, August Merz, A. G. Rosengarten, and Salmon W. Wilder. To this considerable task these men have given many hours and much thought, for their reading has been far from cursory. Hardly a chapter has come back from these friendly critics without some comment, some correction, some additional fact.

My indebtedness to them all is so great, it seems ungracious to pick among them Messrs. du Pont, Howard, Jeffcott, and MacDowell for special thanks. Dr. MacDowell placed at my disposal much unpublished material on the Chemicals Division of the War Industries Board and the American Peace Commission—correspondence, then-confidential reports, his personal notebooks—and he has taken infinite pains to help me unravel the tangled records of wartime controls and German chemical reparations. Mr. Howard also sent me valuable firsthand data: the manuscript copy of his business reminiscences, letters, and copies of his own reports. Mr. Jeffcott furnished a great deal of background material and has been especially helpful in his illuminating comments and suggestions as to where additional information might be found. Mr. du Pont has been a notably faithful, sincere critic and so great has been his interest, that he sent a number of the chapters to his associates, friends, competitors—men he knew were well qualified to pass judgment upon particular portions of the work.

William J. Hale and Warren W. Watson read all of Volume II and N. E. Bartlett and A. L. Loebenberg, all of Volume III. Through the good offices of H. F. Bulkley and T. C. Fetherston, various members of the Union Carbide & Carbon Corporation staff have read the entire manuscript and cooperated in many ways most actively. Robert T. Baldwin, George O. Curme, Jr., Willard H. Dow, Charles Raymond

Downs, M. H. Haertel, A. P. Howes, Elvin H. Killheffer, John R. M. Klotz, George W. Merck, and Charles L. Parsons have all been more than usually helpful.

No one man can possibly be familiar with all the ramifications of the American chemical industry, and though the twenty years during which I occupied an especially favorable observation post gave me a broad view and good perspective, they also taught me to be distrustful of the record as published in trade papers and government reports. Accordingly, I determined to submit every chapter to several men who had firsthand knowledge of the events set forth. In this way I hoped to achieve greater factual accuracy and, with the benefit of such inside points of view, a better insight into causes and effects. These men—many of them old friends—have not disappointed me. They range from college professors to sales managers; men connected with big corporations and modest partnerships in almost every branch of the chemical industry.

The footnotes testify that even eyewitnesses do not always see the same events in the same light and that these readers do not always agree with the author's diagnosis or approve his conclusions. But it is worthy of record, I think, that in hundreds of letters and personal interviews it has only once been hinted that it would be politic to tamper with the facts. This does not surprise me, but I suspect that it will astonish many who seem to believe that American industry, and notably the chemical industry, is rapacious, unscrupulous, selfishly monopolistic, and that there is a great deal in its past that it would like to keep hidden.

Many companies have made freely available to me many unpublished facts from their records, and to them and to the following individuals my sincere thanks are due:

Allen Abrams
Roger Adams
Horace M. Albright
*Carl L. Alsberg
Carl G. Amend
George A. Anderson
*Arthur A. Backus
*Leo H. Baekeland
*Frederick M. Becket
Walter C. Bennett
*Edmund Billings, Jr.
Elmer K. Bolton
Henry Bower
Horace Bowker
C. R. Bragdon
Charles J. Brand
Frank G. Breyer
Fred L. Brooke
Benjamin T. Brooks
Sandford Brown
Burton T. Bush
Edward H. Carus
Arthur D. Chambers
John A. Chew
Ralph N. Chipman
*H. O. Chute
Alan A. Claflin
J. T. Claiborne, Jr.
S. DeWitt Clough
W. K. Coolidge
D. W. Coutlee
J. H. Critchett
Joseph S. Davis
Arthur L. Day
R. H. de Greeff
Henry W. Denny
Ralph E. Dorland
J. V. N. Dorr
W. W. Duecker
Pierre S. du Pont
H. W. Elley
H. S. Emlaw
H. S. Farleigh
Thomas H. Farrell
Alex C. Fergusson
Charles J. Ferry
Chester G. Fisher
E. M. Flaherty
C. C. Furnas
Edward W. Furst
N. Harold Fyffe

H. H. Garis
Ernest V. Gent
A. E. Gibbs
J. M. Goetchius
Harry A. Gomans
Robert P. Gould
*William M. Grosvenor
Ivan Gubelmann
C. M. Hallett
William A. Hamor
Carl Haner
Glenn L. Haskell
Albert W. Hawkes
Ernst A. Hauser
R. C. Hedke
Roy L. Hill
Maurice Holland
Harry M. Hooker
Roger W. Hooker
C. L. Huisking
Samuel Isermann
*Martin H. Ittner
S. W. Jacobs
C. A. Jacobson
David W. Jayne
Wilber Judson
H. M. Kaufmann
R. K. Kennedy
Allan F. Kitchel
S. D. Kirkpatrick
Hugo L. Kleinhaus
August Klipstein
W. S. Landes
*Walter S. Landis
F. A. Lidbury
Leland Lyon
Ralph H. McKee
G. D. McLaughlin
Ira P. MacNair
Charles A. Mace
Joseph B. Magnus
Percy C. Magnus
Stephen L. Mahyam
Lewis H. Marks
Theodore Marvin
E. W. Maynard
C. E. K. Mees
F. J. Metzger
Carl S. Miner
C. L. Modesitt
John M. Morehead
J. J. Moosmann
A. Cressy Morrison
H. R. Morrison
Edward J. Muhs
H. R. Murdock
Walter J. Murphy
Paul I. Murrill
Howard S. Neiman
Louis A. Olney
S. B. Penick
J. T. Power
Robert J. Quinn
C. J. Ramsburg
William M. Rand
F. W. Rockwell
E. E. Routh
F. W. Russe
E. A. Rykenboer
J. R. Schmertz
Herman Seydel
J. A. Singmaster
*Fin Sparre
E. C. Speiden
David Spence
S. J. Spitz
C. M. A. Stine
F. E. Stockelbach
E. C. Sullivan
John Swenehart
Robert L. Taylor
A. A. Teeter
Sydney Thayer, Jr.
William B. Thom
E. C. Thompson
John F. Thompson
Philip S. Tilden
A. G. Treadgold
Bronson B. Tufts
F. M. Turner
J. W. Turrentine
S. L. Tyler
J. R. Van Fleet
C. C. Van Nuys
E. A. Van Valkenburgh
Theodore P. Walker
R. Righton Webb
Edward R. Weidlein
John M. Weiss
George D. Welles, Jr.
Milton C. Whitaker
Walter Wilkinson
Eli Winkler
Joseph Wrench
B. H. Young
F. G. Zinsser

* Deceased.

I cannot hope that in such a voluminous work, covering so wide a field and so tightly packed with facts and figures, some errors have not crept in, and I remember with gratitude how many have been caught and corrected by these critics. Not they, but I am responsible for any mistakes that do occur in these pages, and while I profited greatly by their comments and opinions, the interpretations of events and the conclusions drawn are wholly mine.

To the Library of the Chemists' Club, the late Emily J. Fell, and her successor, Doris Dart, this work owes a great deal more than I can adequately express, and to its Trustees I am indebted for permission to use as illustrations the photographs from the Club Album of members. As always, Sally Coy and the staff of the Westerly (R. I.) Public Library have taken endless trouble to assist me, and I and my research assistants have had unusual courtesies from the New York Public Li-

brary and the Libraries of the New York Academy of Medicine and Yale University. The Mathieson Alkali Works has for a year housed my assistants in their New York offices, giving much more than "desk space," a generous service that greatly expedited our labors and for which we are all sincerely grateful. United States Industrial Chemicals, Inc., is at present extending the same courtesies toward the completion of this work.

I owe a particular debt to those who as researchers and secretaries have been closely associated with this work. The exigencies of the war have forced many changes in my little staff—I lost two excellent secretaries to the Armed Services—but without exception my assistants have worked at their very exacting tasks with enthusiasm and loyalty and good judgment. From first to last Jean Pinchack has led the research work and her interest and scrupulous exactitude, her knowledge of chemistry and "the literature," her practical experience in editorial work, have been invaluable to me. Carol Johnson and Elaine Davenport, both of whom left to be married, and Joan McElligott, now working on material for subsequent volumes, have each contributed to the onerous task of collecting data and checking references. Among the several secretaries who have served me during the past three years, Joyce Johnson and Barbara Trumbull deserve my special thanks.

WILLIAMS HAYNES

COMPANY AND PERSONAL NAME INDEX

Portraits indicated by asterisk * or dagger † (Vol. III); references by italicized number.

SUBJECT INDEX

Statistics (prices, imports, exports, tariff, production, etc.) indicated by italics.